

Life Sciences On File



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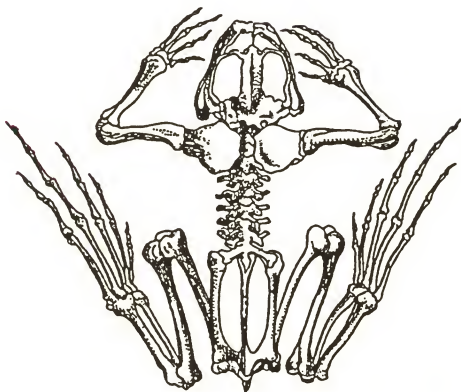
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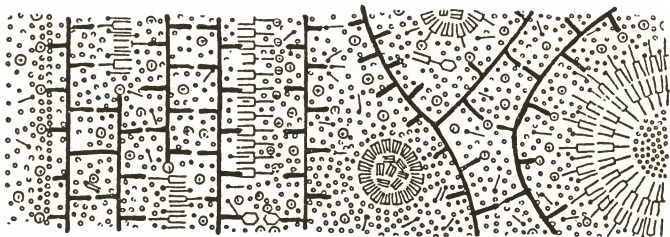
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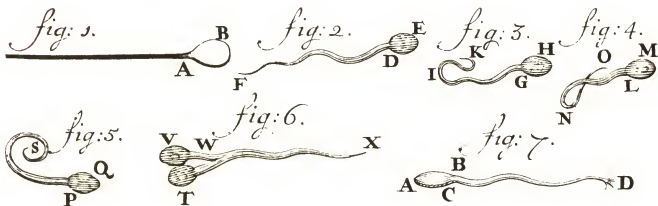
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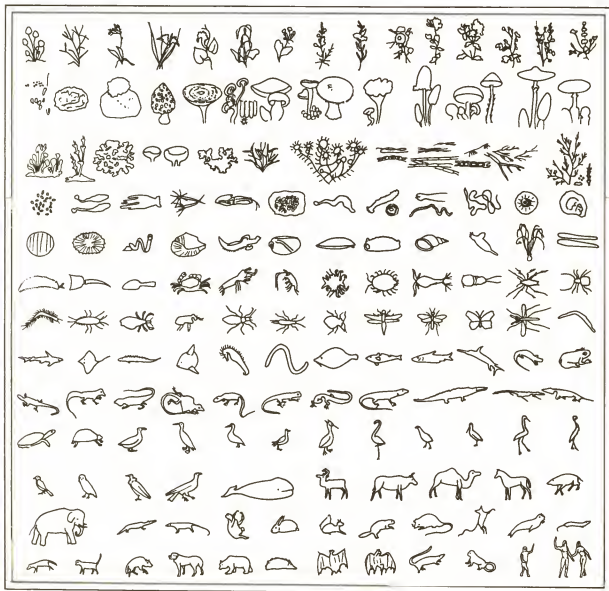
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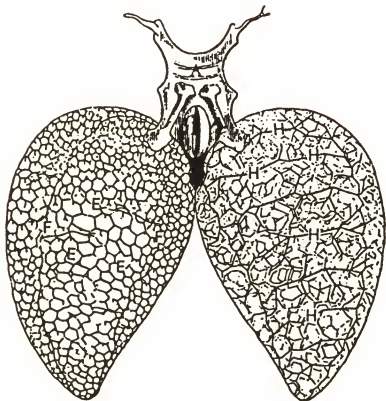
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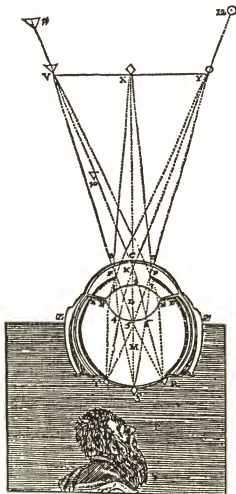
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04.022	Respiration: plants		



HUMAN BIOLOGY

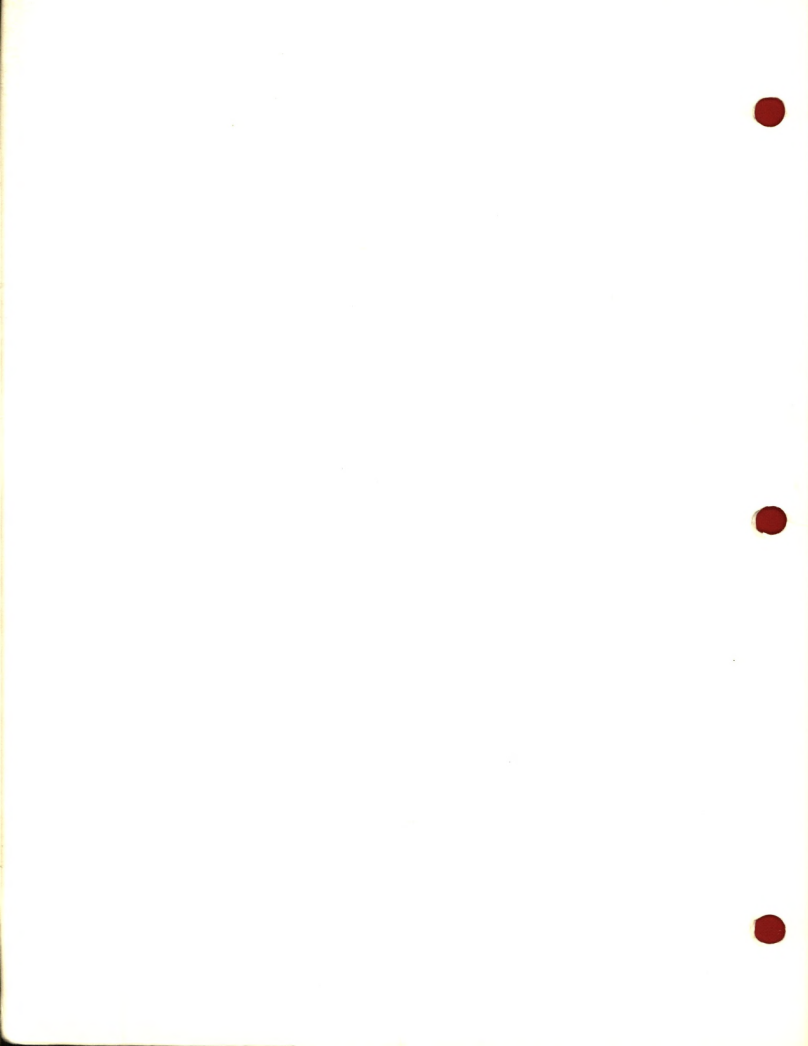
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05.002	Nutrition: teeth	05.029	Excretion: skin structure
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05.026	Excretion: kidney structure 1	05.053	Locomotion: limb movement
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ECOLOGY

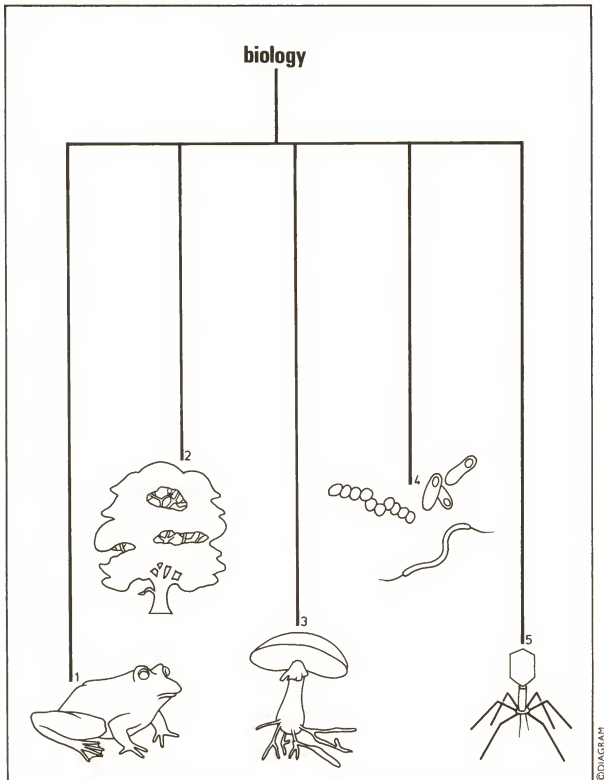
- 06.001 Terrestrial biomes
- 06.002 Carbon cycle
- 06.003 Nitrogen cycle
- 06.004 Water cycle
- 06.005 Energy flow
- 06.006 Food chain
- 06.007 Pyramid of biomass
- 06.008 Food web





Major branches of biology

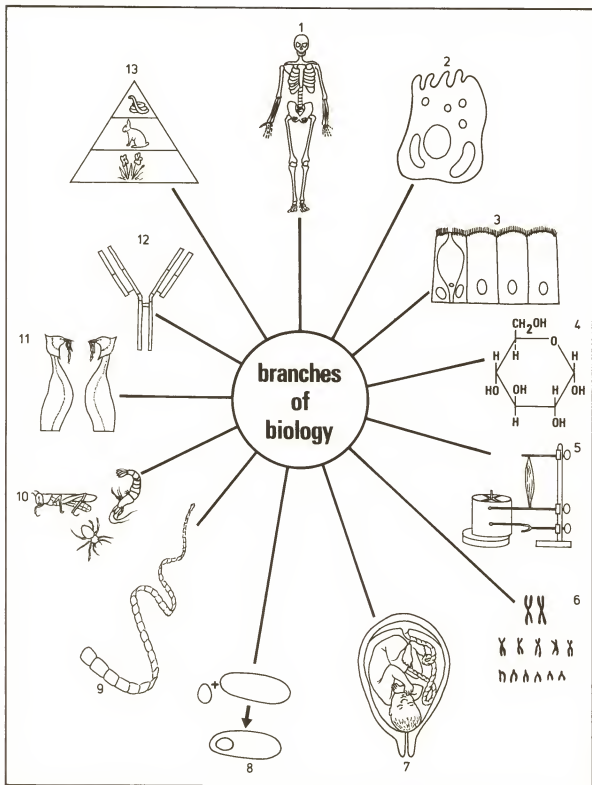
01.001



- 1 Zoology (animals)
- 2 Botany (plants)
- 3 Mycology (fungi)
- 4 Bacteriology (bacteria)
- 5 Virology (viruses)

Branches of biology

01.002

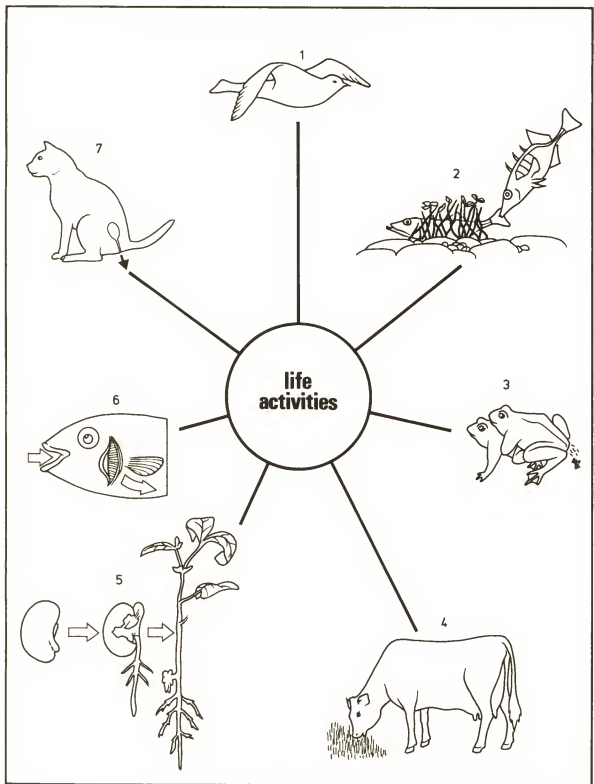


- 1 Anatomy (internal structure)
- 2 Cytology (cells)
- 3 Histology (tissues)
- 4 Biochemistry (biological reactions)
- 5 Physiology (internal function)
- 6 Genetics (heredity)
- 7 Embryology (development)
- 8 Biotechnology (genetic engineering)
- 9 Parasitology (parasites)

- 10 Taxonomy (classification)
- 11 Ethology (behavior)
- 12 Immunology (immunity)
- 13 Ecology (environment)

Life activities

01.003

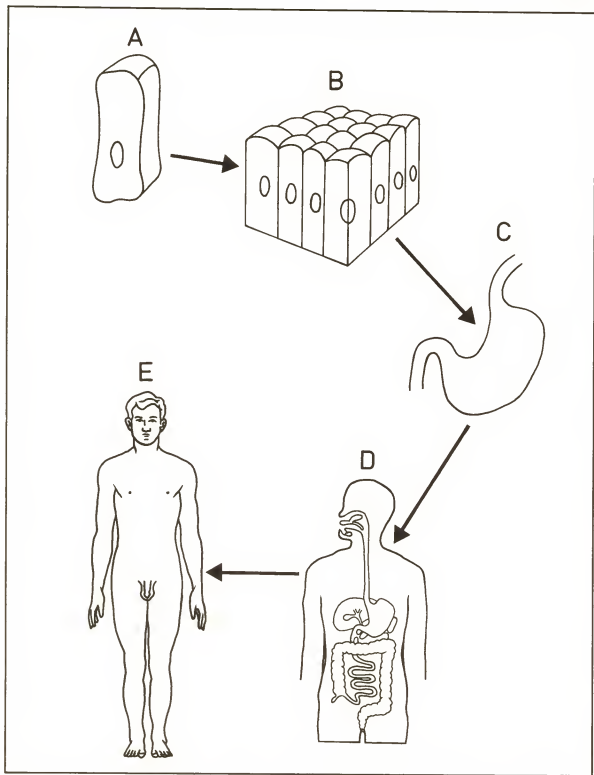


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- 1 Movement
- 2 Sensitivity
- 3 Reproduction
- 4 Nutrition
- 5 Growth
- 6 Respiration
- 7 Excretion

Levels of organization

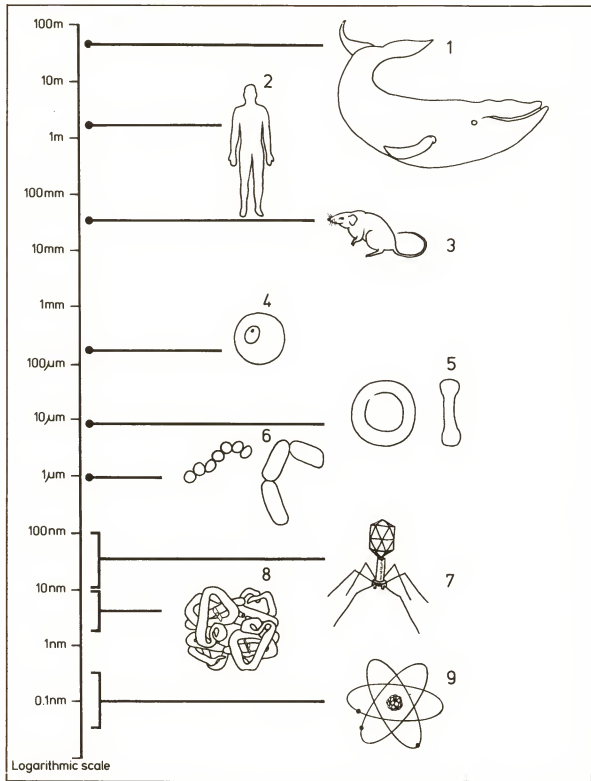
01.004



- A Cell (columnar epithelial cell)
- B Tissue (columnar epithelium)
- C Organ (stomach)
- D System (digestive)
- E Organism (*Homo sapiens*)

Units of measurement

01.005

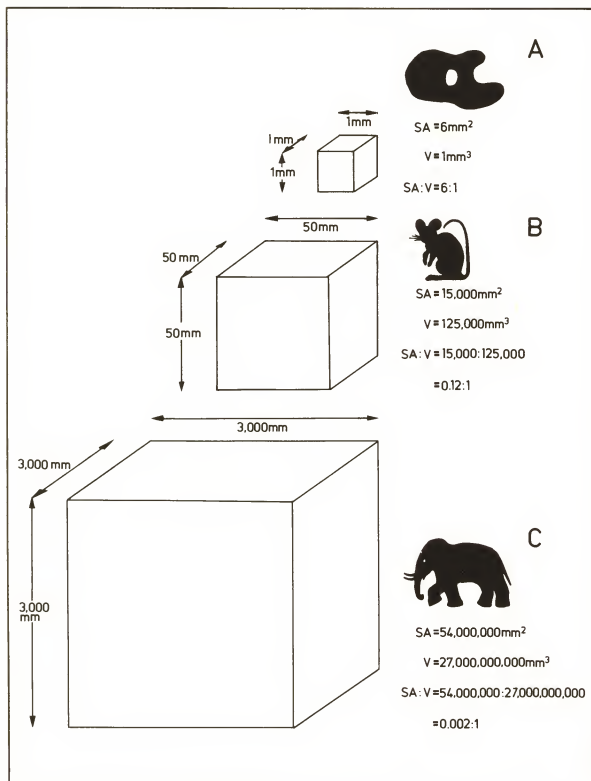


- 1 Whale
- 2 Human
- 3 Mouse
- 4 Human egg
- 5 Red blood cell
- 6 Bacteria
- 7 Viruses
- 8 Proteins
- 9 Atoms

mm = millimeter
µm = micrometer
nm = nanometer
1000 nm = 1 µm
1000 µm = 1 mm

Surface area: volume ratio

01.006



A comparison of surface area to volume ratios in three organisms. The cubes represent the approximate dimensions of the three organisms.

A *Amoeba*

B Mouse

C Elephant

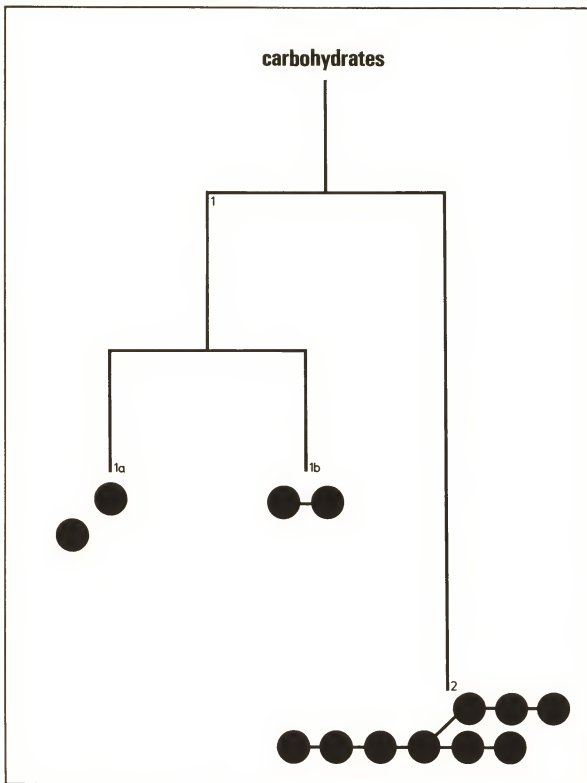
SA = Surface area (mm^2)

V = Volume (mm^3)

SA:V = Surface area:volume ratio

Classification of carbohydrates

01.007



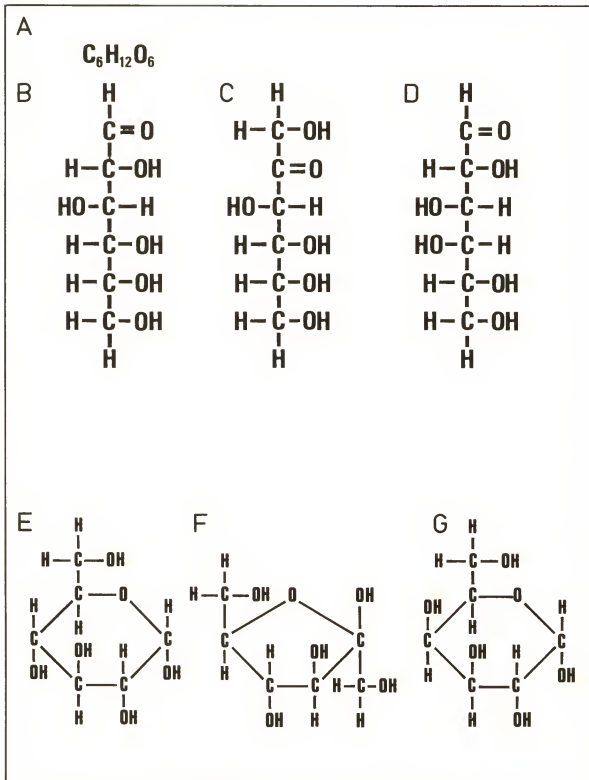
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- 1 Sugars
- 1a Monosaccharides
 $(CH_2O)_n$
- 1b Disaccharides
 $C_{12}H_{22}O_{11}$
- 2 Polysaccharides
 $C_x(H_2O)_y$

● = single
monosaccharide unit

Monosaccharides

01.008

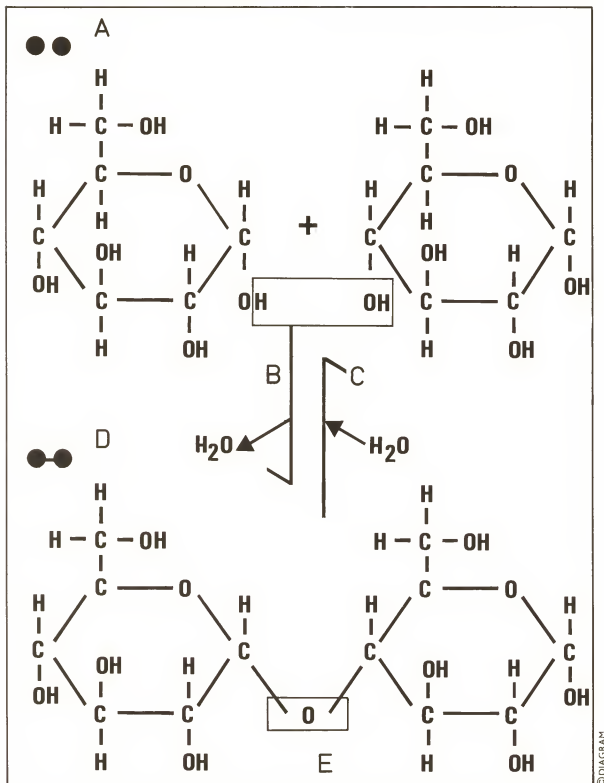


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- A Glucose, fructose, galactose (empirical formula)
 B D-glucose (straight chain form)
 C D-fructose (straight chain form)
 D D-galactose (straight chain form)
 E α-D glucose (pyranose ring)
 F α-D fructose (furanose ring)
 G α-D galactose (pyranose ring)

Disaccharide synthesis and hydrolysis

01.009

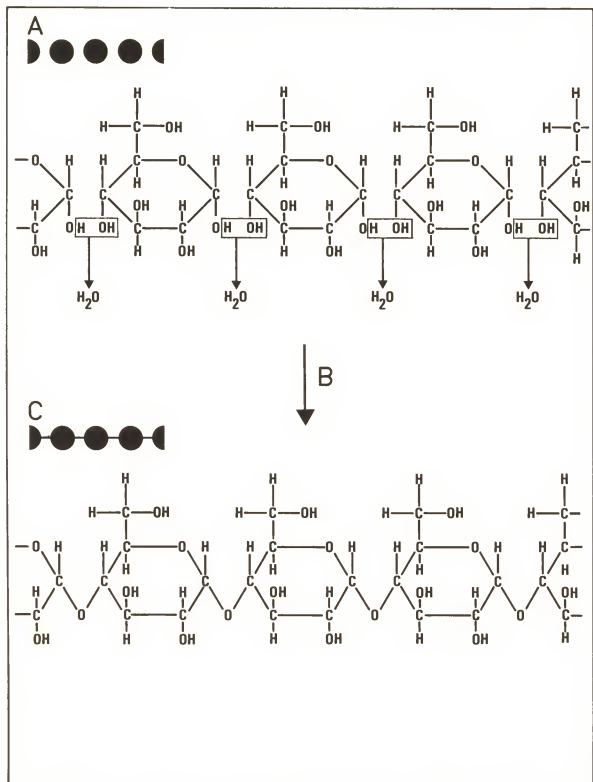


© DIAGRAM

- A Two α glucose molecules
B Dehydration synthesis
C Hydrolysis
D Maltose
E Glycosidic bond

Starch synthesis

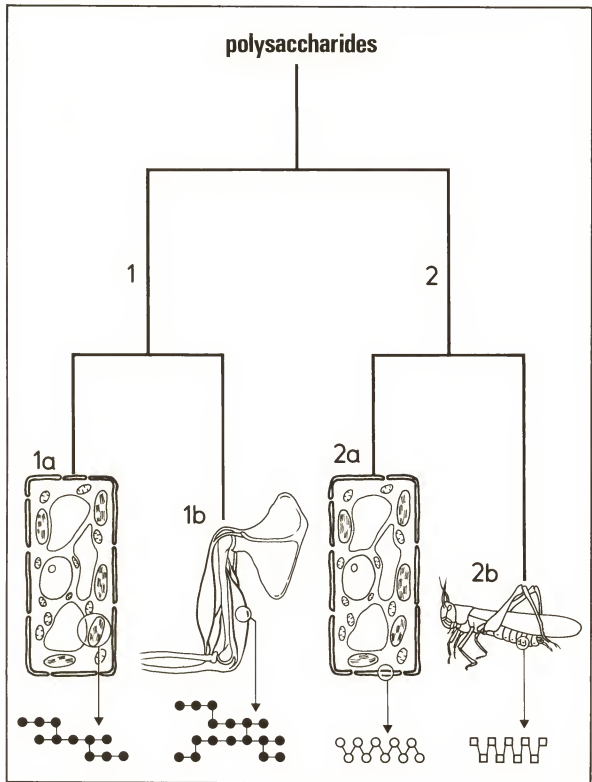
01.010



- A α -D glucose
molecules
B Dehydration
synthesis
C Starch molecule

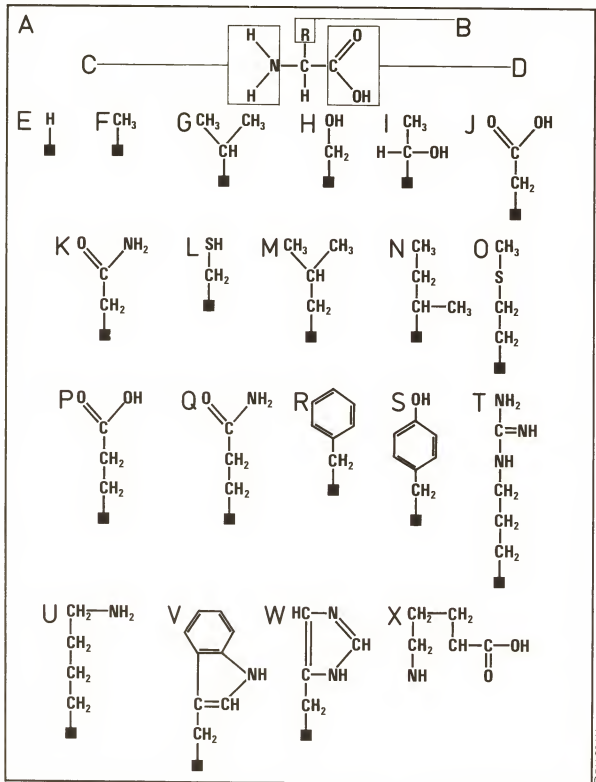
Important polysaccharides

01.011



Amino acids

01.012



- A** Generalized amino acid structure
B Variable group (R)
C Amino group (basic)
D Carboxyl group (acidic)
E-X Amino acids
 ■ Non-variable part of amino acid molecule

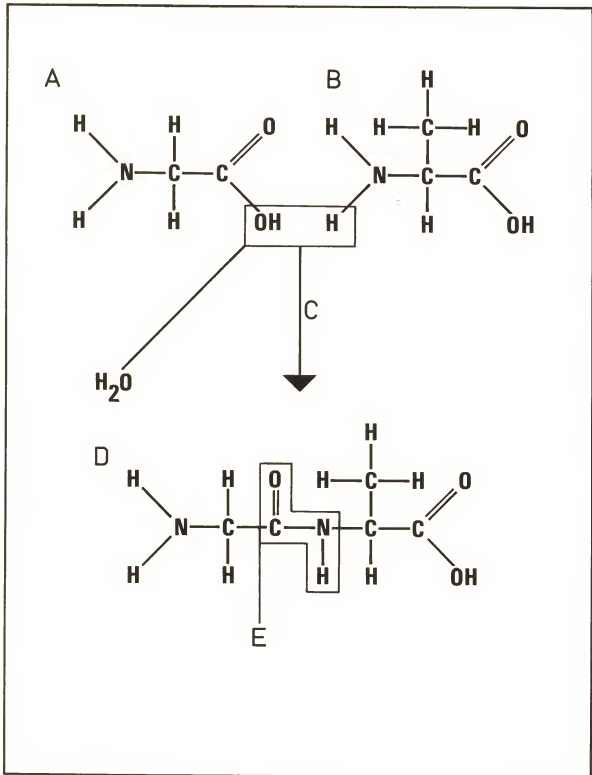
- E** Glycine (gly)
F Alanine (ala)
G Valine (val)
H Serine (ser)
I Threonine (thr)
J Aspartic acid (asp)
K Asparagine (asn)
L Cysteine (cys)
M Leucine (leu)

- N** Isoleucine (ile)
O Methionine (met)
P Glutamic acid (glu)
Q Glutamine (gln)
R Phenylalanine (phe)
S Tyrosine (tyr)
T Arginine (arg)
U Lysine (lys)
V Tryptophan (trp)

- W** Histidine (his)
X Proline (pro)

Dipeptide synthesis

01.013

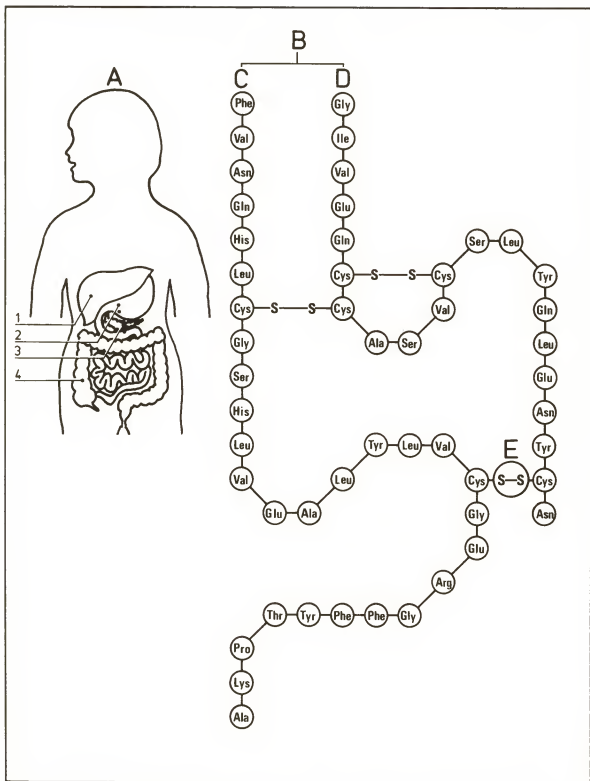


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- A Glycine (gly)
- B Alanine (ala)
- C Dehydration synthesis
- D Dipeptide: glycylalanine (gly-ala)
- E Peptide bond

Protein structure

01.014



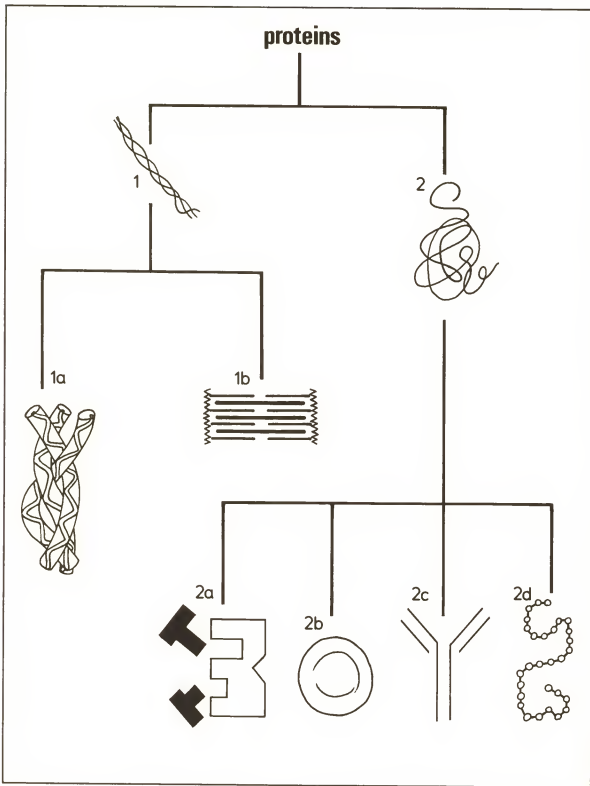
- A Human body showing position of pancreas
B Insulin (produced in pancreas)
C B-polypeptide chain
D A-polypeptide chain
E Sulfur bridge

- 1 Liver
2 Stomach
3 Pancreas
4 Intestine

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Classification of proteins

01.015

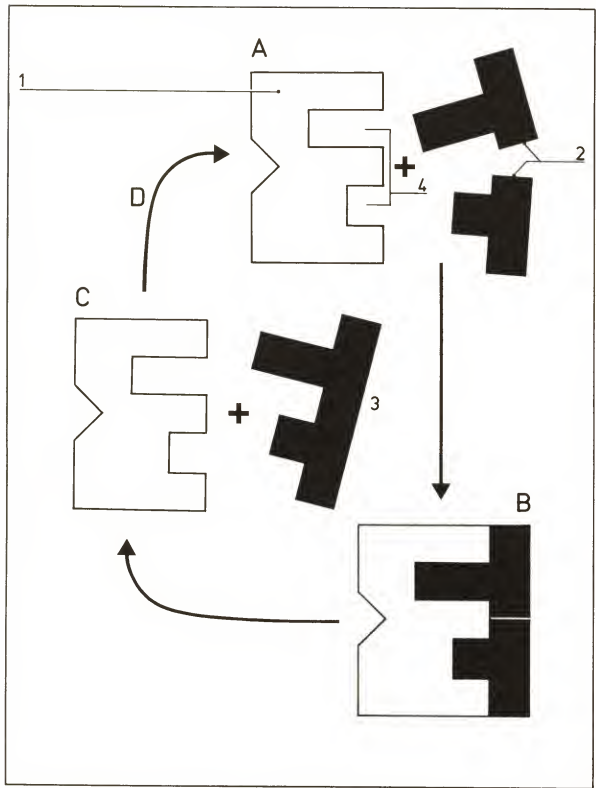


- 1 Fibrous
- 1a Structural (eg collagen)
- 1b Contractile (eg myosin)
- 2 Globular
- 2a Enzymes
- 2b Transport (eg hemoglobin)

- 2c Protective (eg antibodies)
- 2d Hormones (eg insulin)

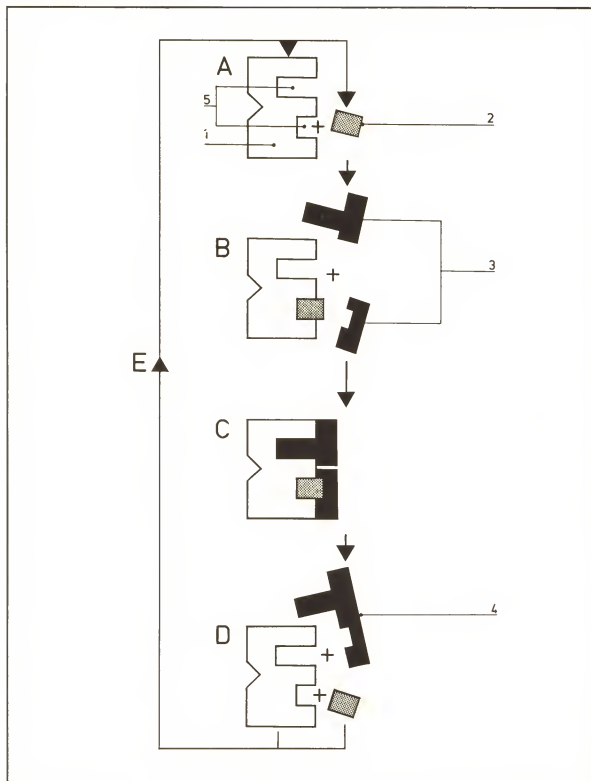
Enzymes: mechanism

01.016



Enzymes and coenzymes

01.017



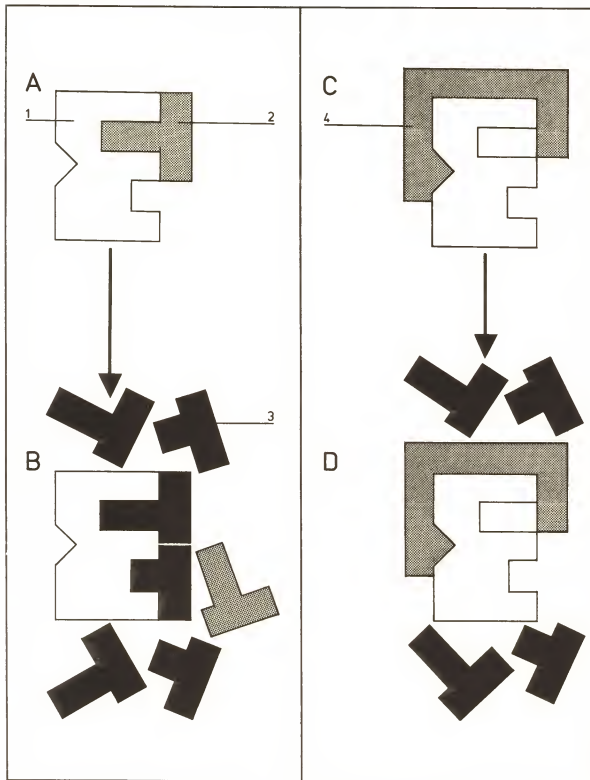
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- A Enzyme + coenzyme
- B Enzyme + coenzyme + substrate molecules
- C Enzyme-substrate complex
- D Enzyme + coenzyme + product
- E Unchanged enzyme + coenzyme used again

- 1 Enzyme
- 2 Coenzyme
- 3 Substrate molecules
- 4 Product molecule
- 5 Active site

Enzymes and inhibitors

01.018

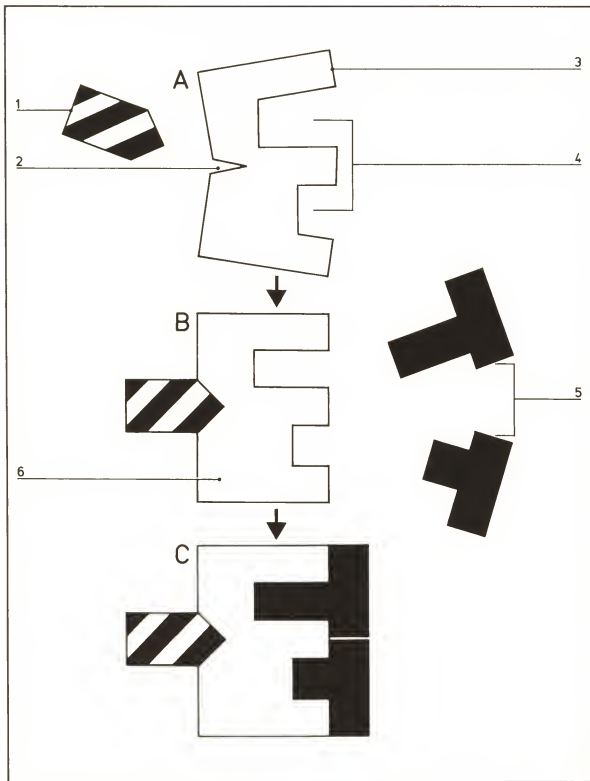


- A Competitive inhibitor binds to active site and blocks it
B Inhibitor displaced by excess substrate molecules
C Noncompetitive inhibitor binds to another part of enzyme and blocks active site
D Inhibitor not displaced by excess substrate molecules

- 1 Enzyme
2 Competitive inhibitor
3 Substrate molecules
4 Noncompetitive inhibitor

Allosteric enzymes

01.019



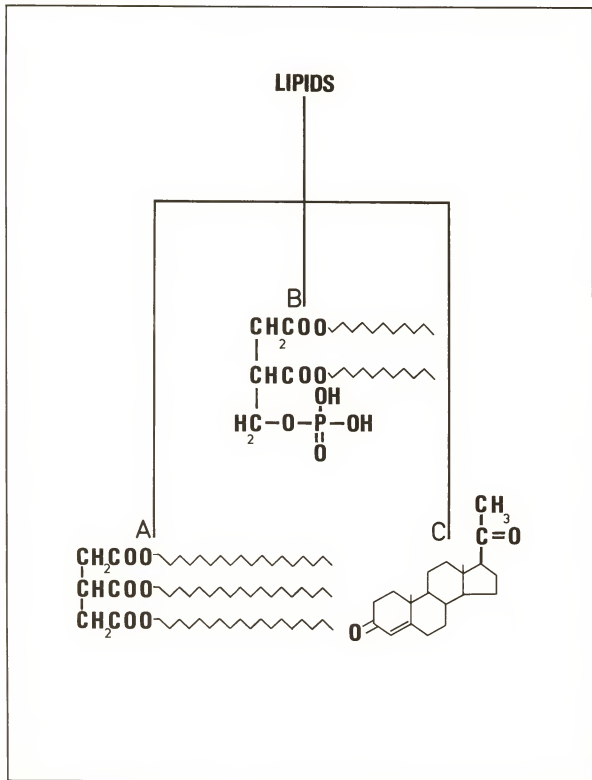
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- A Inactive form of enzyme and positive modulator
B Modulator binds to enzyme and activates it
C Substrate molecules bind to active site to form enzyme-substrate complex

- 1 Positive modulator
2 Modulator binding site
3 Inactive enzyme
4 Active site
5 Substrate molecules
6 Active form of enzyme

Classification of lipids

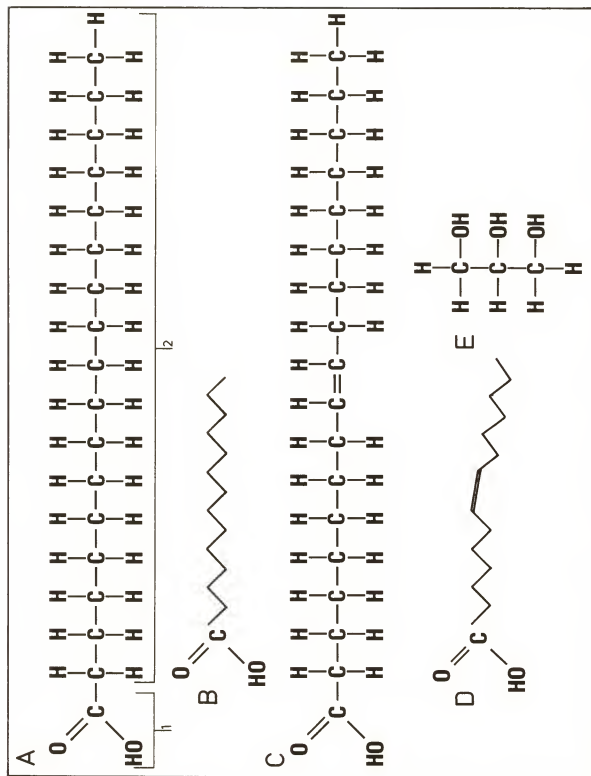
01.020



- A Triglyceride (neutral fat)
B Phospholipid
C Steroid

Fatty acids and glycerol

01.021

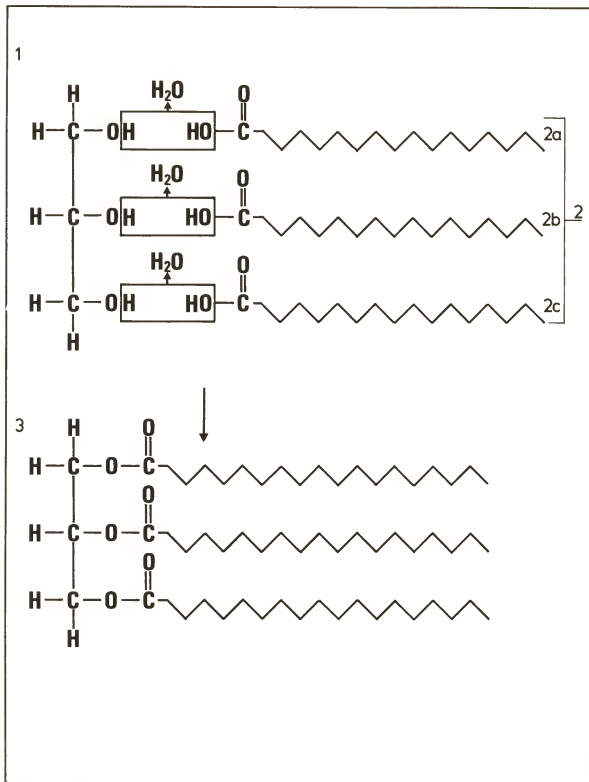


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- A Stearic acid (saturated) - molecular structure
B Stearic acid - model
C Oleic acid (unsaturated) - molecular structure
D Oleic acid - model
E Glycerol - molecular structure
1 Acid head (polar)
2 Hydrocarbon tail (non-polar)

Triglyceride formation

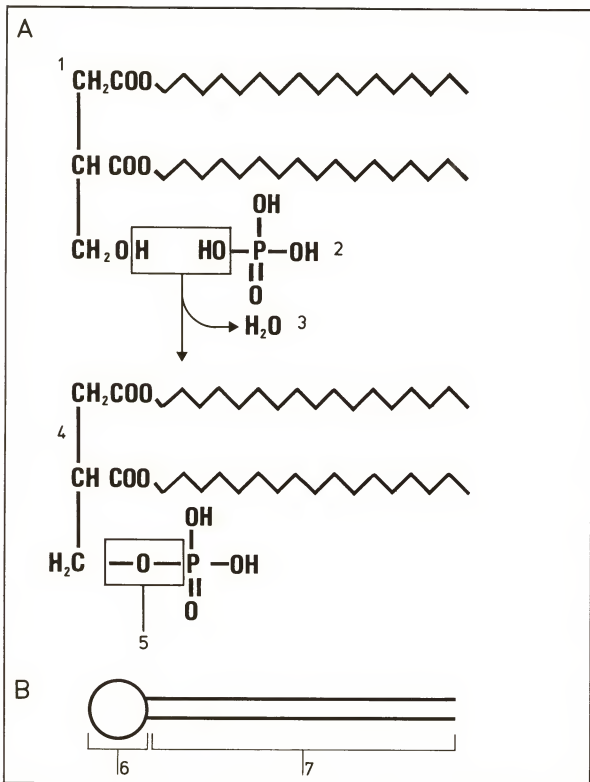
01.022



- 1 Glycerol molecule
- 2 Three fatty acid molecules
- 2a Stearic acid
- 3 Tristearin (triglyceride)

Phospholipids

01.023

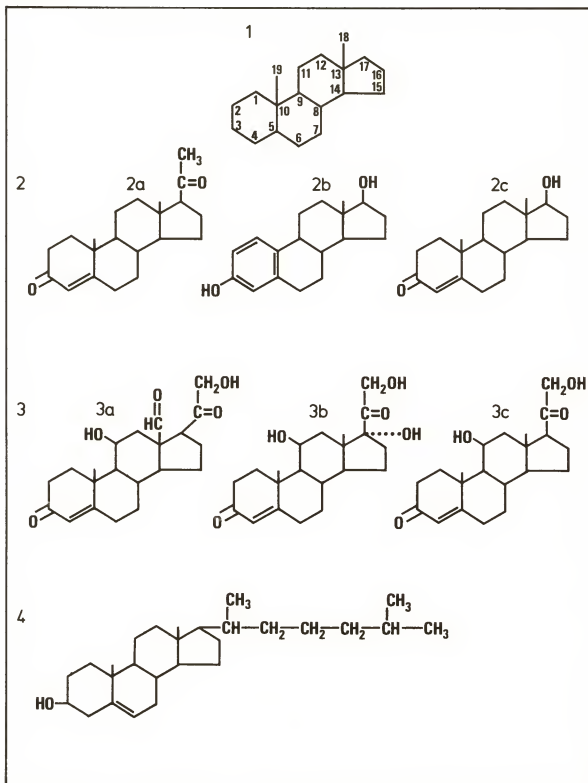


A Phospholipid formation
B Model of phospholipid

- 1 Diglyceride molecule
- 2 Phosphoric acid molecule
- 3 Condensation reaction
- 4 Phospholipid
- 5 Phosphoester bond
- 6 Hydrophilic end (polar group containing phosphate)
- 7 Hydrophobic end (non-polar hydrocarbon tails)

Steroids

01.024

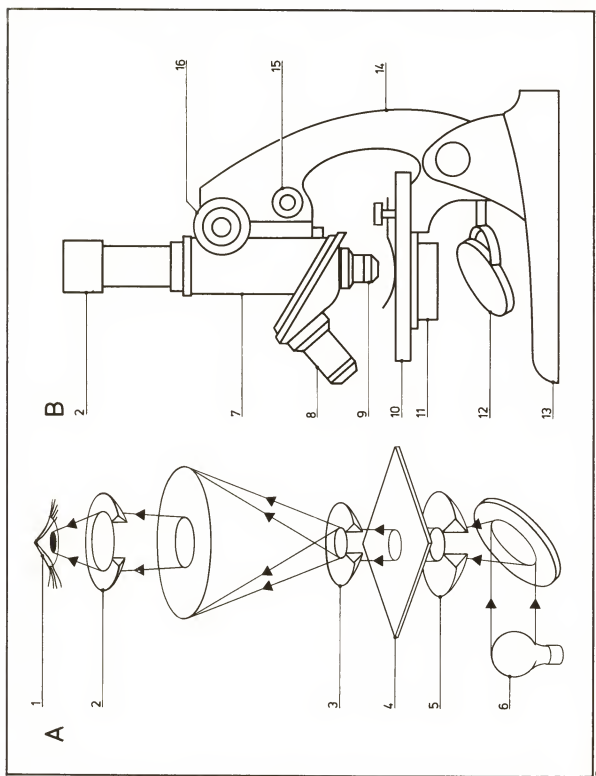


- 1 Basic steroid structure
2 Sex hormones
2a Progesterone
2b Estradiol-17 β
2c Testosterone
3 Adrenal cortex hormones
3a Aldosterone

- 3b Cortisol
3c Corticosterone
4 Cholesterol

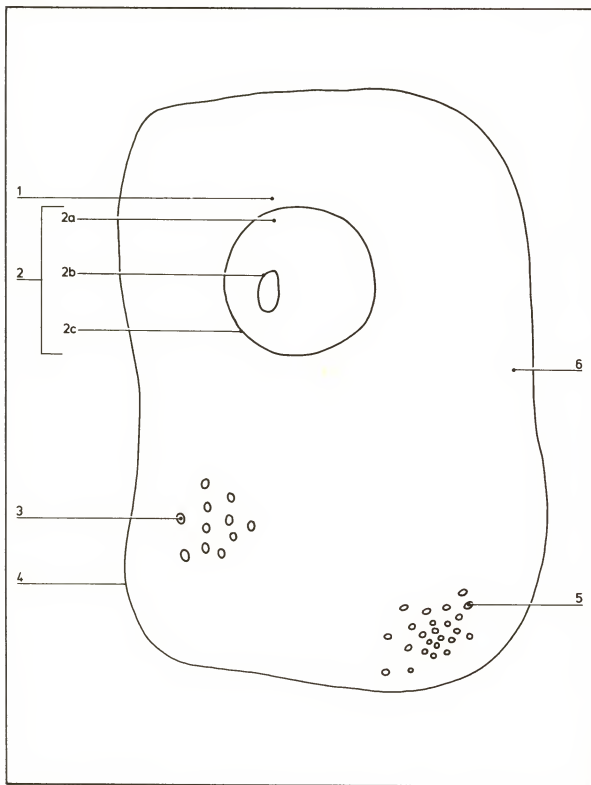
Light microscope

01.025



Animal cell: light microscope

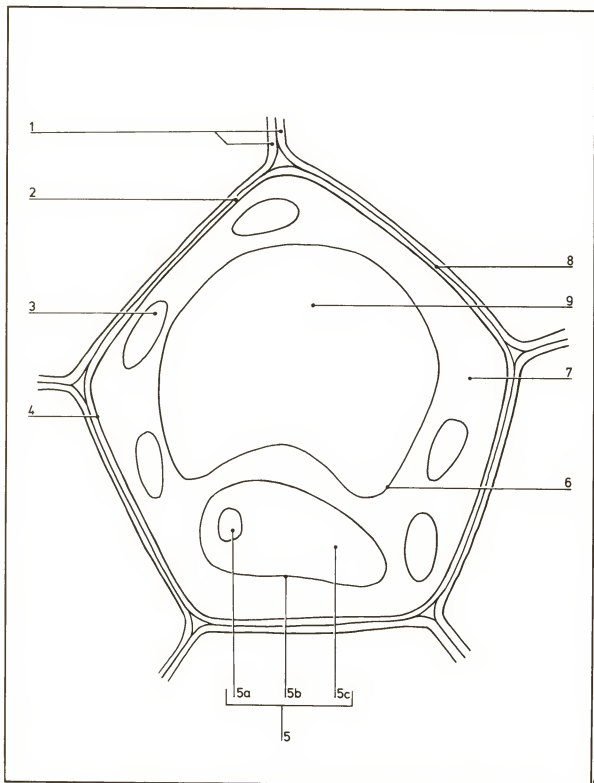
01.026



- 1 Centriole
- 2 Nucleus
- 2a Nucleoplasm
- 2b Nucleolus
- 2c Nuclear membrane
- 3 Food granules
- 4 Plasma membrane
- 5 Secretory granules
- 6 Cytoplasm

Plant cell: light microscope

01.027



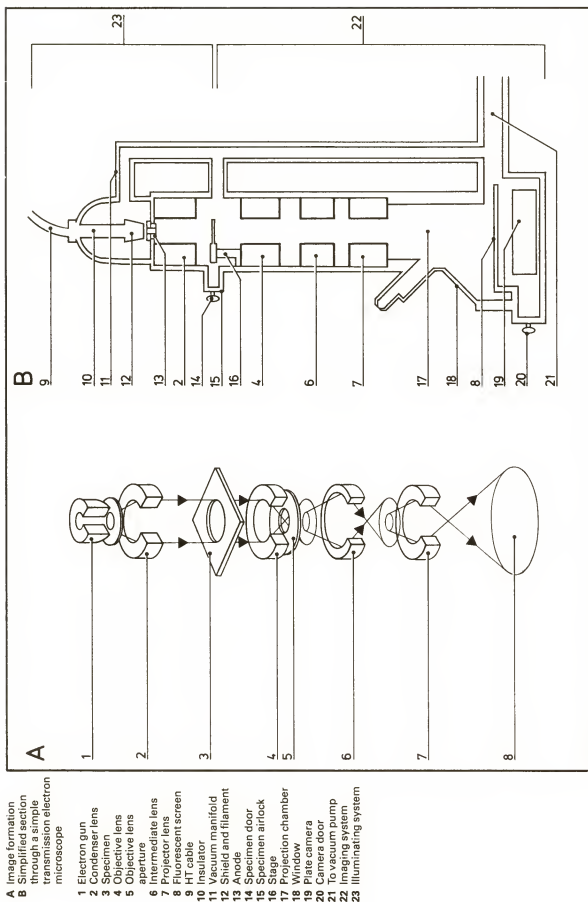
- 1 Cell walls of neighboring cells
- 2 Cell wall
- 3 Chloroplast
- 4 Plasma membrane
- 5 Nucleus
- 5a Nucleolus
- 5b Nuclear membrane
- 5c Nucleoplasm

- 6 Tonoplast
- 7 Cytoplasm
- 8 Middle lamella
- 9 Vacuole

© DIAGRAM

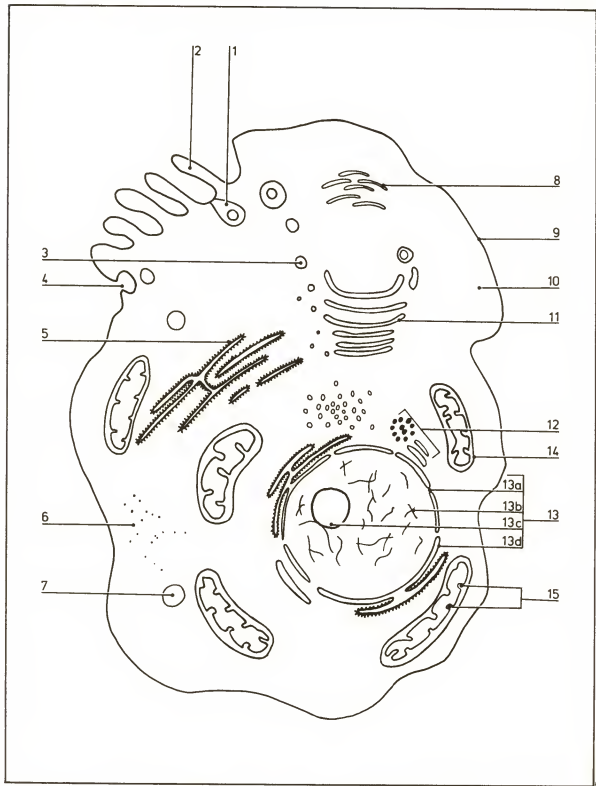
Electron microscope

01.028



Animal cell: electron microscope

01.029



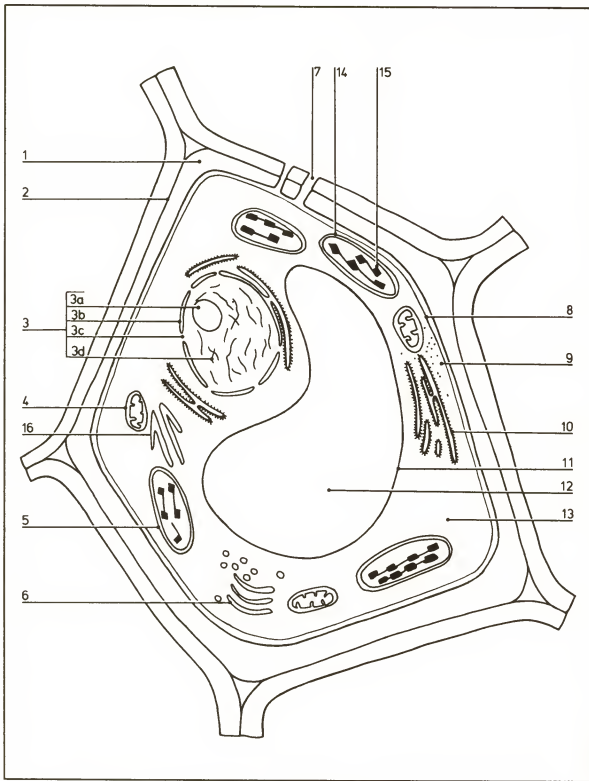
- 1 Exocytotic vesicle
- 2 Microvillus
- 3 Golgi vesicle
- 4 Pinocytotic vesicle
- 5 Rough endoplasmic reticulum
- 6 Ribosome
- 7 Lysosome
- 8 Smooth endoplasmic

- reticulum
- 9 Cell membrane
- 10 Cytoplasm
- 11 Golgi apparatus
- 12 Centrioles
- 13 Nucleus
- 13a Nuclear pore
- 13b Chromatin
- 13c Nucleolus

- 13d Nuclear envelope
- 14 Mitochondrion
- 15 Cristae

Plant cell: electron microscope

01.030

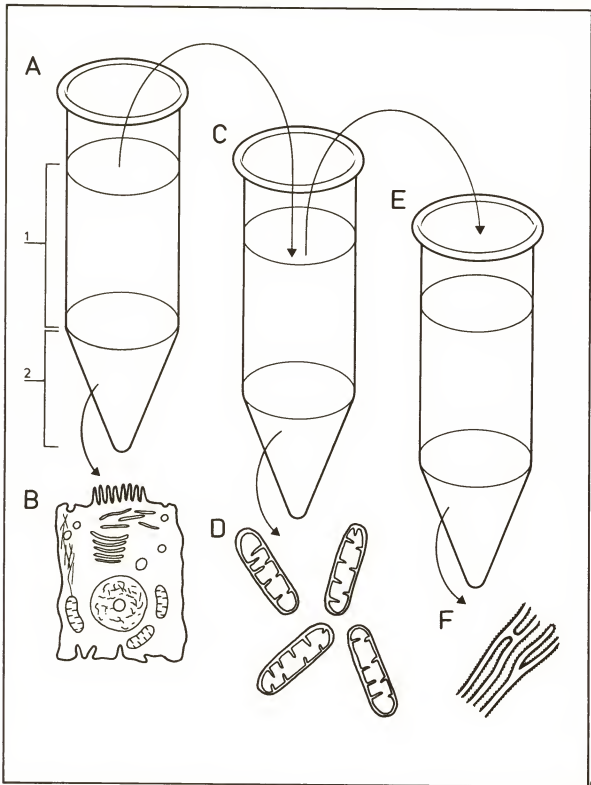


©DIAGRAM

- | | | |
|---------------------|---------------------------------|---------------------------------|
| 1 Cell wall | 6 Golgi apparatus | 13 Cytoplasm |
| 2 Middle lamella | 7 Plasmodesma | 14 Chloroplast envelope |
| 3 Nucleus | 8 Cell membrane | 15 Granum |
| 3a Nucleolus | 9 Ribosome | 16 Smooth endoplasmic reticulum |
| 3b Nuclear envelope | 10 Rough endoplasmic reticulum | |
| 3c Nuclear pore | 11 Vacuole membrane (tonoplast) | |
| 3d Chromatin | 12 Vacuole | |
| 4 Mitochondrion | | |
| 5 Chloroplast | | |

Cell fractions produced by differential centrifugation

01.031

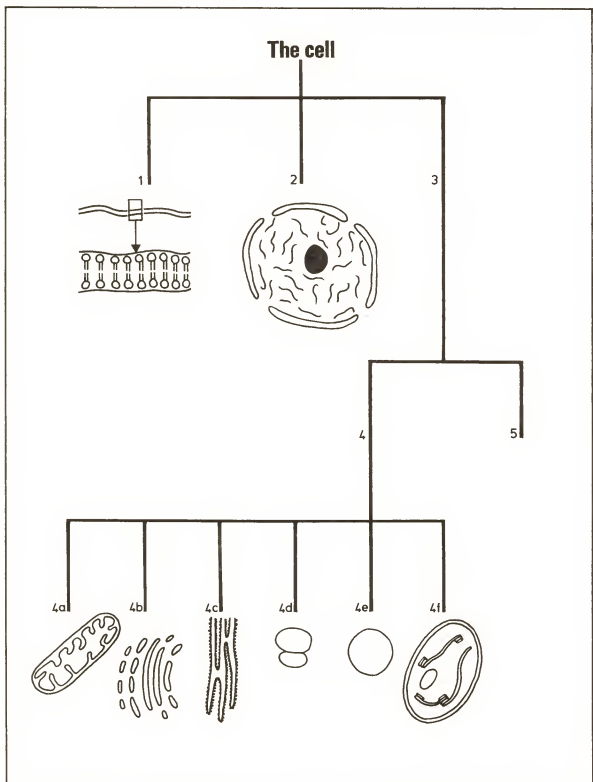


- A Cell homogenate spun at 600g for 10 minutes
- B Intact cells, nuclei
- C Supernatant from A spun at 10,000g for 20 minutes
- D Mitochondria
- E Supernatant from C spun at 100,000g for 60 minutes
- F Ribosomes and endoplasmic reticulum

- 1 Supernatant
- 2 Sediment

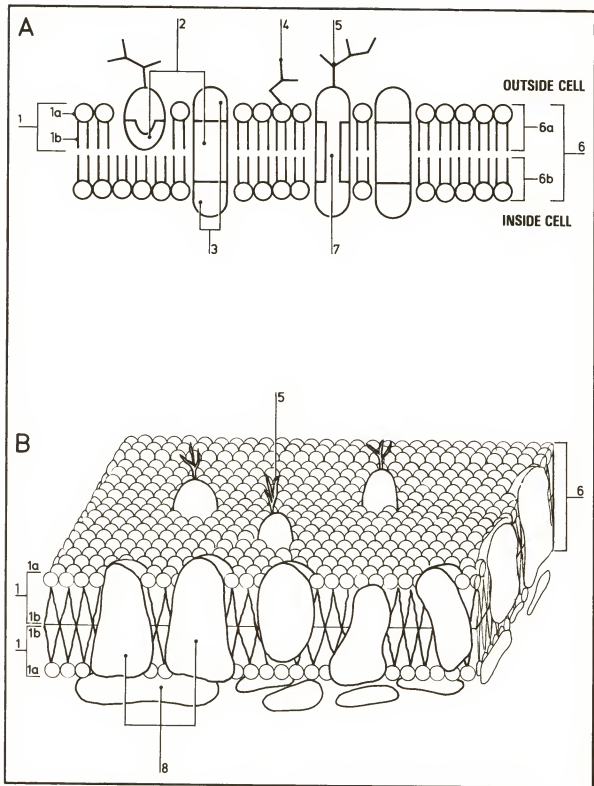
Classification of cell contents

01.032



Plasma membrane: structure

01.033



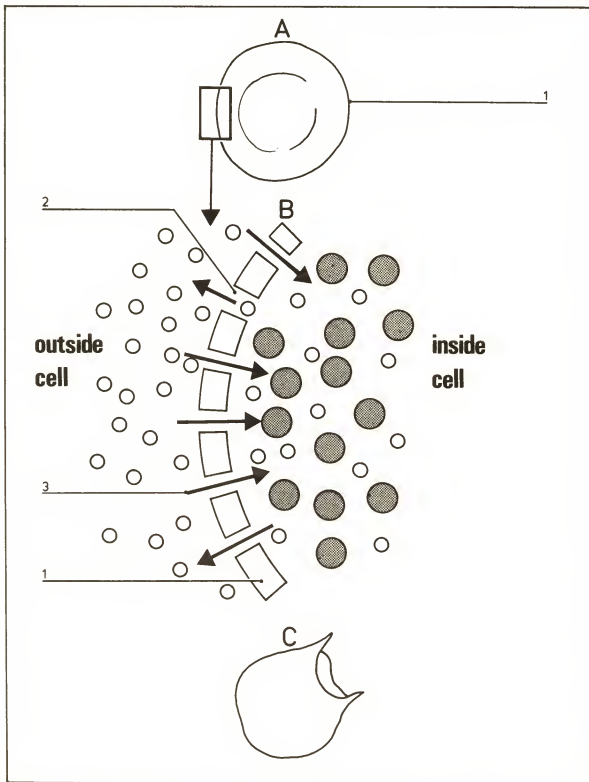
A Fluid mosaic model of membrane structure
B Three-dimensional model of membrane structure

- 1 Phospholipid
- 1a Hydrophilic head
- 1b Hydrophobic tail
- 2 Hydrophobic regions of proteins
- 3 Hydrophilic regions of proteins
- 4 Glycolipid

- 5 Glycoprotein
- 6 Lipid bilayer
- 6a External layer
- 6b Internal layer
- 7 Hydrophilic channel
- 8 Membrane proteins

Plasma membrane: osmosis

01.034

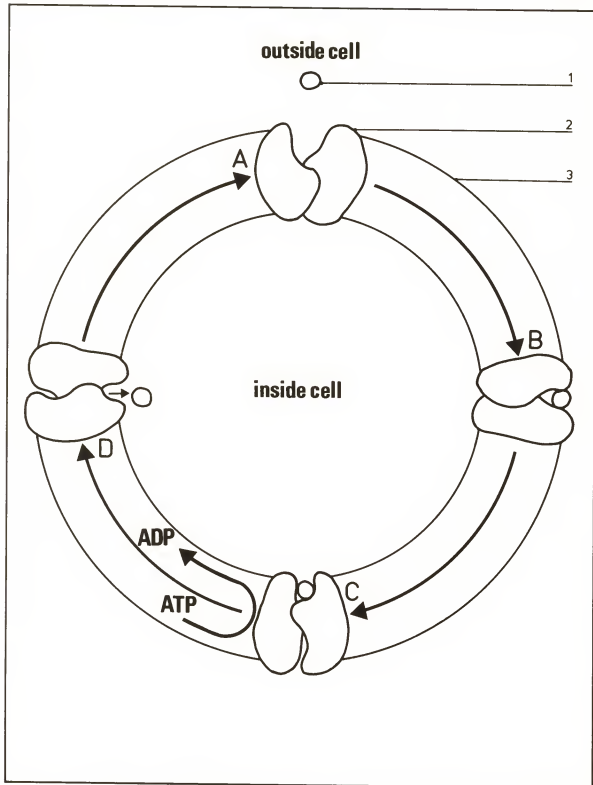


- A Red blood cell placed in water
B Model showing osmosis across red blood cell membrane
C Red blood cell takes in water and bursts

- 1 Plasma membrane
2 Pore in membrane
3 Arrow indicating movement of water

Plasma membrane: active transport

01.035

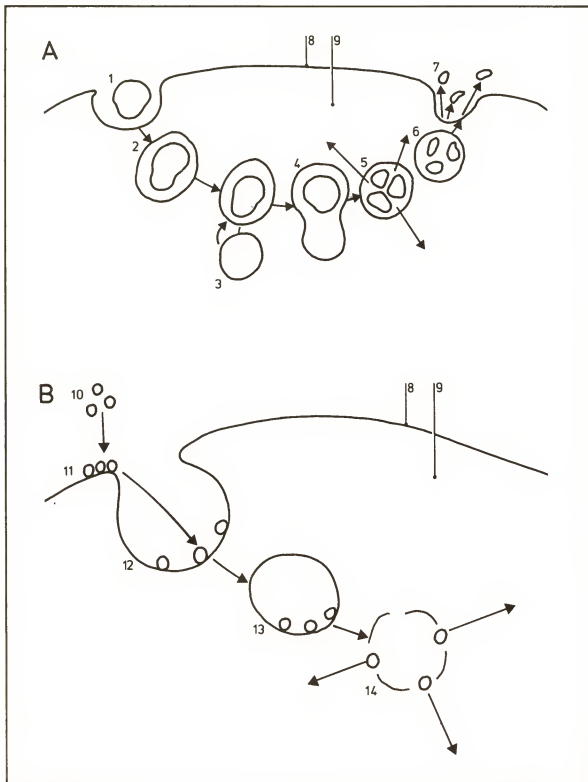


- A Passenger molecule moves toward carrier protein
B Passenger molecule binds to carrier protein
C Energy release from ATP (adenosine triphosphate) causes conformational change in carrier protein
D Passenger molecule released into cytoplasm

- 1 Passenger molecule
2 Carrier protein
3 Plasma membrane

Plasma membrane: endocytosis

01.036



A Phagocytosis

B Pinocytosis

1 Large particle taken up by phagocytosis

2 Particles enclosed in vacuole

3 Lysosome

4 Lysosome fuses with vacuole

5 Digestion occurs in vacuole and products are absorbed

6 Vacuole with waste products moves toward cell membrane

7 Exocytosis of waste product

8 Plasma membrane

9 Cytoplasm

10 Small particles

11 Adsorption to cell surface

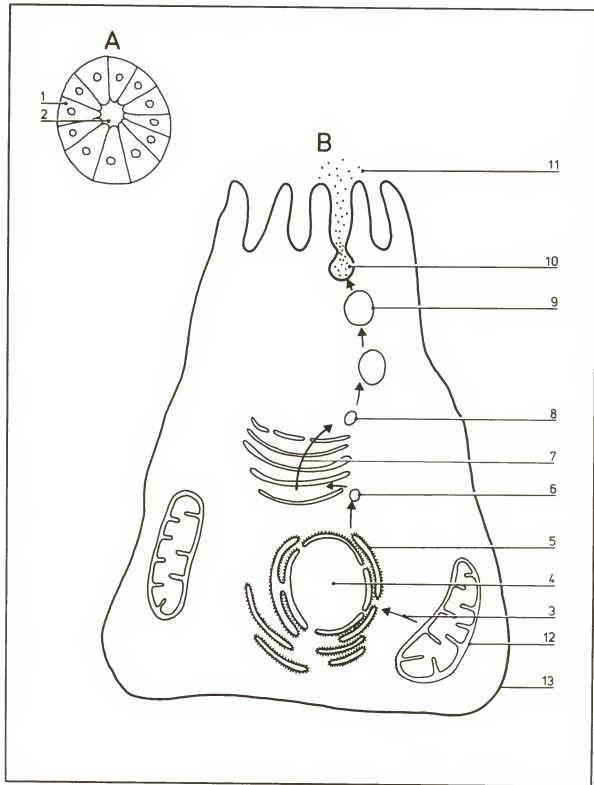
12 Invagination

13 Vacuole formed

14 Vacuole breaks down releasing particles into cytoplasm

Exocytosis

01.037



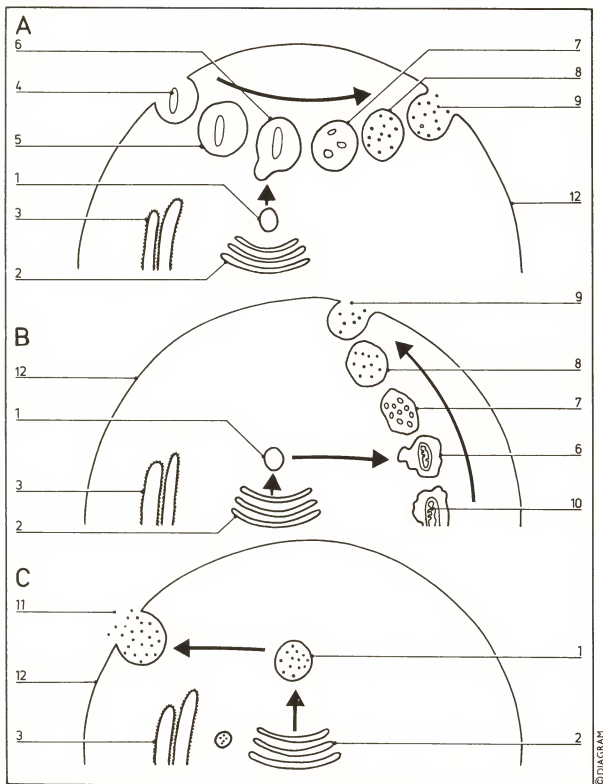
A Pancreatic duct (transverse section)
B Pancreatic duct (acinar) cell illustrating secretory exocytosis

- 1 Acinar cell
- 2 Fine branch of pancreatic duct
- 3 Energy used in protein synthesis
- 4 Nucleus
- 5 Rough endoplasmic reticulum produces and

- 6 transports proteins
- 7 Vesicle from rough endoplasmic reticulum
- 8 Proteins move through Golgi apparatus
- 9 Golgi vesicle
- 10 Mature secretory granule
- 11 Exocytosis
- 12 Inactive enzyme (zymogen)
- 13 Mitochondrion
- 14 Plasma membrane

Lysosomes

01.038



A Lysosomes and phagocytosis

B Lysosomes and autophagy

C Lysosomes and the release of enzymes by exocytosis

1 Primary lysosome produced by Golgi apparatus

2 Golgi apparatus

3 Rough endoplasmic reticulum

4 Phagocytosis

5 Phagocytic vacuole

6 Secondary lysosome

7 Digestion

8 Residual body

9 Exocytosis

10 Redundant mitochondrion in vacuole

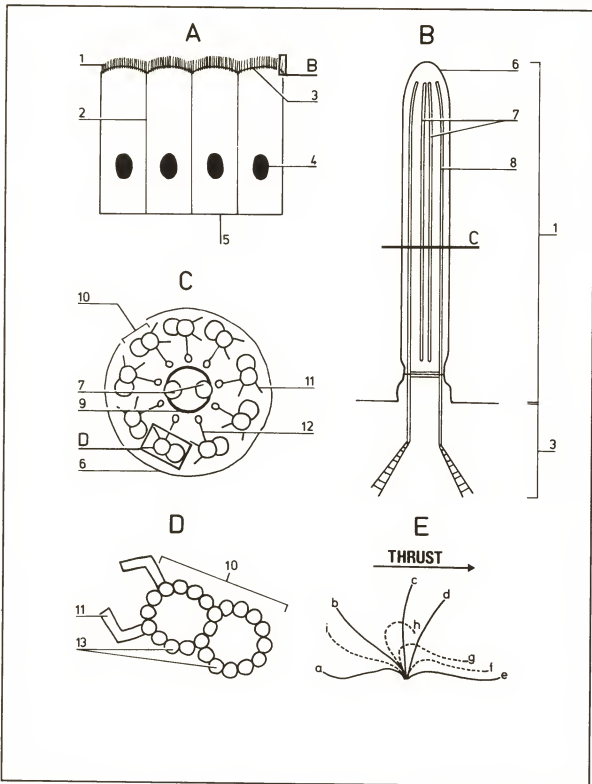
11 Release of lysosomal enzymes by exocytosis

12 Plasma membrane

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Cilia

01.039

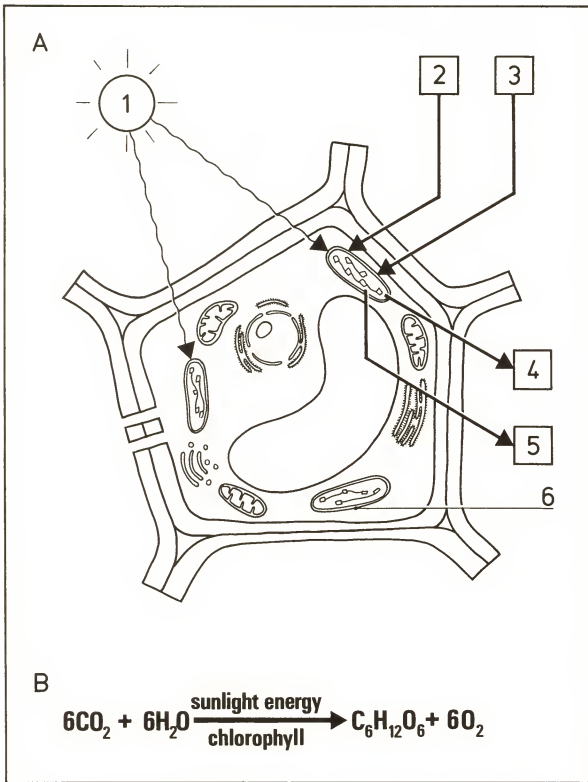


- A Ciliated epithelial cells
B Cilium - longitudinal section
C Cilium - transverse section
D Peripheral filament
E Action of cilium (a - e power stroke; f - i recovery stroke)
- 1 Cilia
 - 2 Cell membrane
 - 3 Basal body

- 4 Nucleus
- 5 Basement membrane
- 6 Plasma membrane
- 7 Central filaments
- 8 Peripheral filament
- 9 Sheath
- 10 Microtubule doublet
- 11 Arm (Dynein-ATPase)
- 12 Spoke
- 13 Tubulin subunits

Summary of photosynthesis 1

01.040

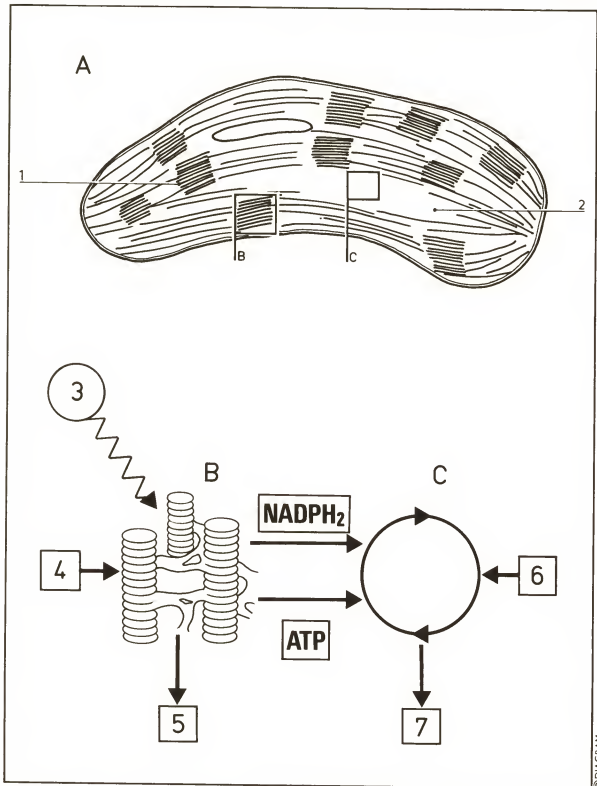


A Plant cell
B Simple equation for photosynthesis

1 Sunlight energy
2 Carbon dioxide
3 Water
4 Glucose
5 Oxygen
6 Chloroplast

Summary of photosynthesis 2

01.041



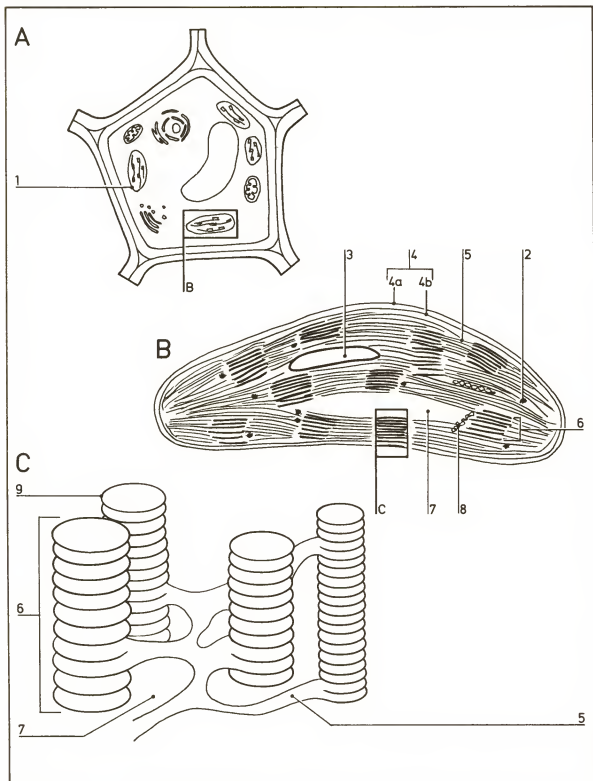
- A Chloroplast
B Light-dependent stage (light reactions) in grana
C Light-independent stage (dark reactions) in stroma

- 6 Carbon dioxide
7 Glucose

- 1 Granum
2 Stroma
3 Sunlight energy
4 Water
5 Oxygen

Chloroplast: structure

01.042



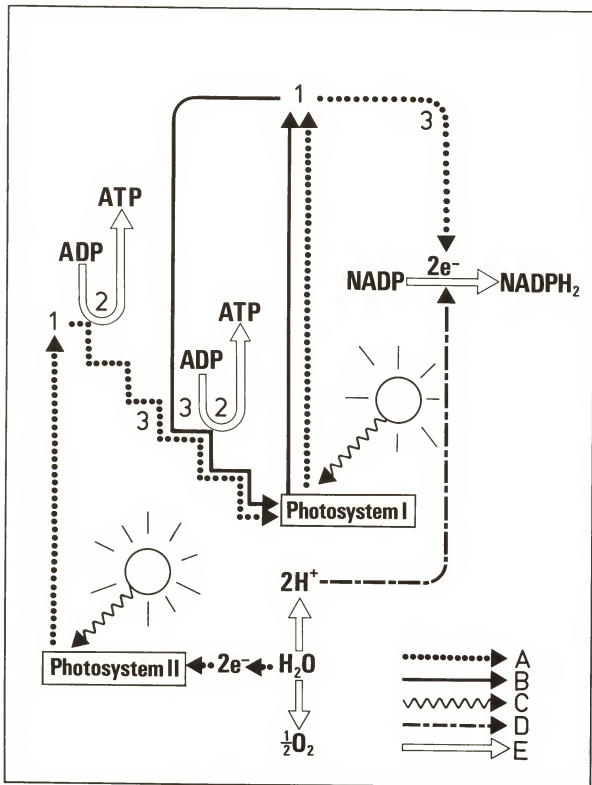
A Plant cell
B Chloroplast
C Detail of granum and intergranum

4a Outer envelope
4b Inner envelope
5 Intergranum
6 Granum
7 Stroma
8 Chloroplast DNA
9 Thylakoid (lamella)

1 Chloroplast
2 Oil droplet
3 Starch grain
4 Chloroplast envelope

Photosynthesis: light-dependent stage (light reactions)

01.043

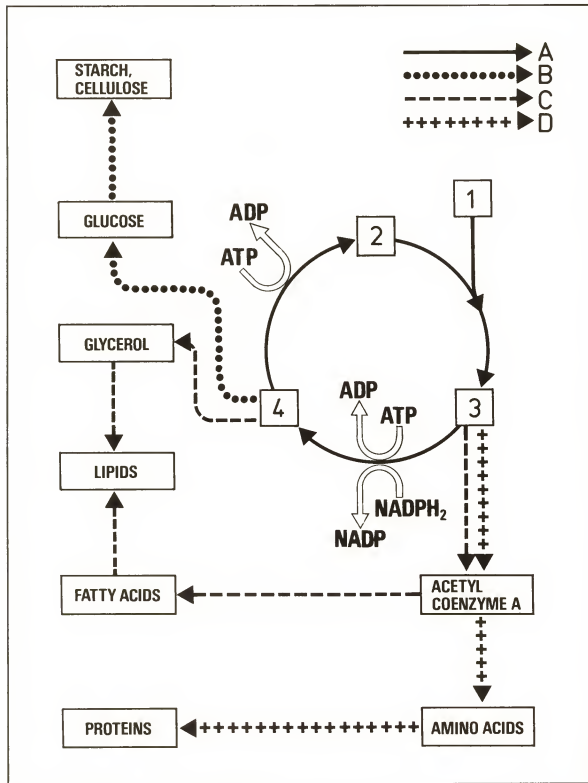


- A Flow of electrons in non-cyclic photophosphorylation
B Flow of electrons in cyclic photophosphorylation
C Sunlight energy
D Passage of protons to NADP
E Other chemical reactions

- 1 Electron acceptor
2 ATP formation from ADP by chemiosmotic mechanism
3 Electron carrier chain

Photosynthesis: light-independent stage (dark reactions)

01.044

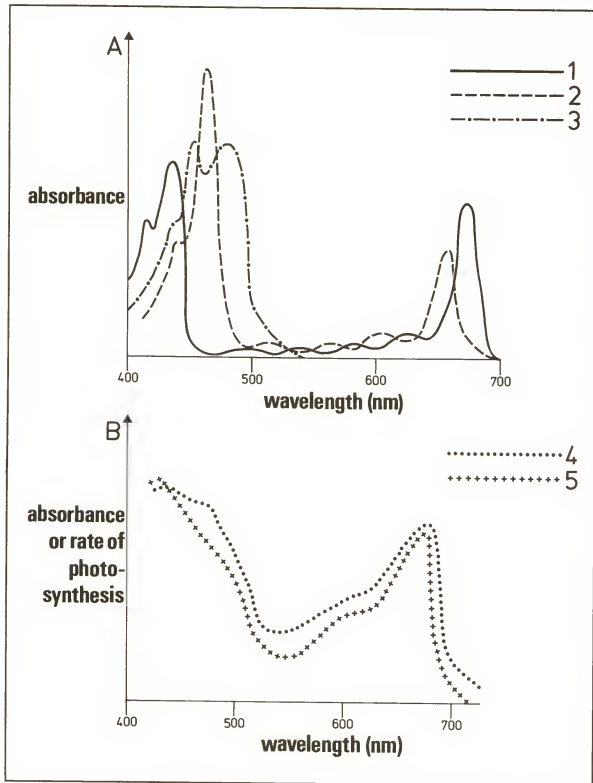


- A Reactions of Calvin cycle
B Carbohydrate synthesis
C Lipid synthesis
D Protein synthesis

- 1 Carbon dioxide (1C)
2 Ribulose diphosphate (5C)
3 Phosphoglyceric acid (3C)
4 Phosphoglyceraldehyde (3C)

Chlorophyll: absorption and action spectra

01.045



A Absorption spectra of chlorophylls a and b, and carotenoids

B Action spectrum for photosynthesis compared with absorption spectrum of photosynthetic pigments

1 Chlorophyll a

2 Chlorophyll b

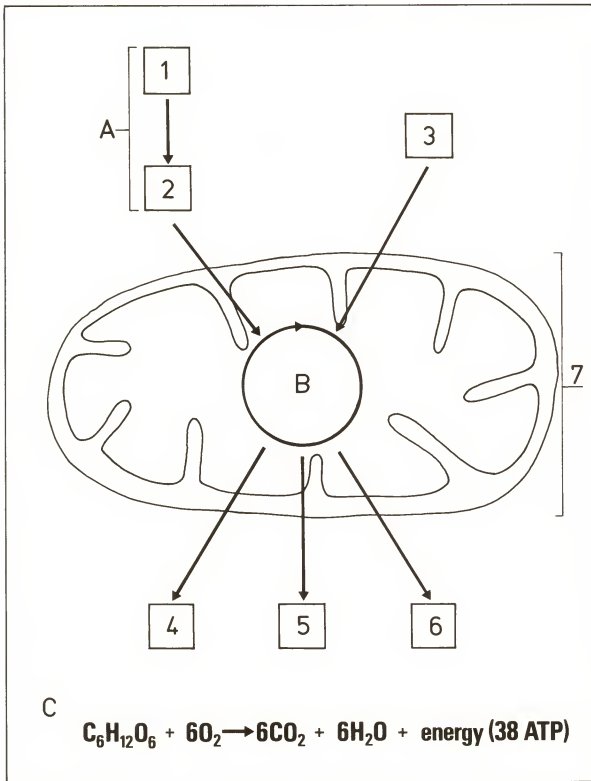
3 Carotenoids

4 Absorption spectrum

5 Action spectrum

Summary of aerobic respiration 1

01.046



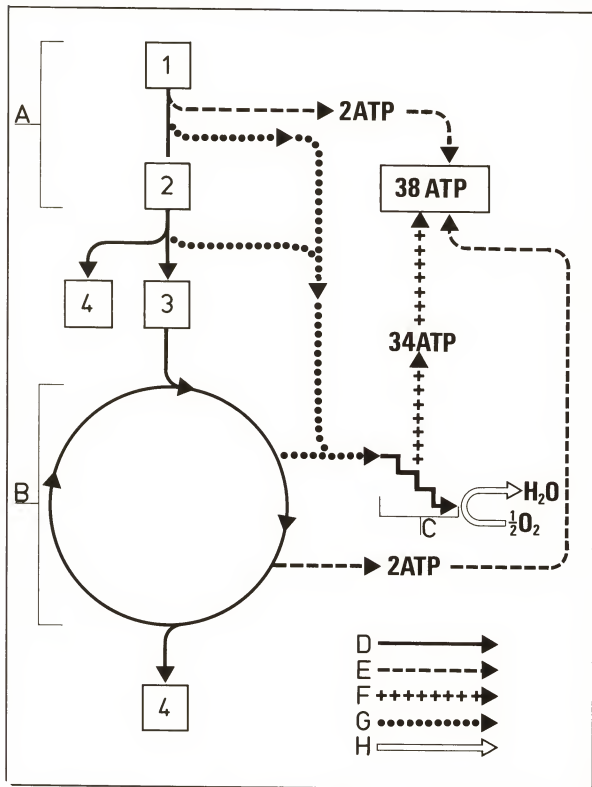
- A Glycolysis (cytoplasm)
B Krebs cycle (mitochondrion)
C Simple equation for aerobic respiration

- 6 Energy (ATP)
7 Mitochondrion

- 1 Glucose
2 Pyruvic acid
3 Oxygen
4 Carbon dioxide
5 Water

Summary of aerobic respiration 2

01.047



©DIAGRAM

A Glycolysis (cytoplasm)

B Krebs cycle (mitochondrion)

C Electron carrier chain (mitochondrion)

D Glycolysis/Krebs cycle reactions

E ATP produced by substrate-level phosphorylation

F ATP produced by oxidative phosphorylation

G Hydrogen transferred by acceptor to electron carrier chain

H Reduction of oxygen to water

1 Glucose

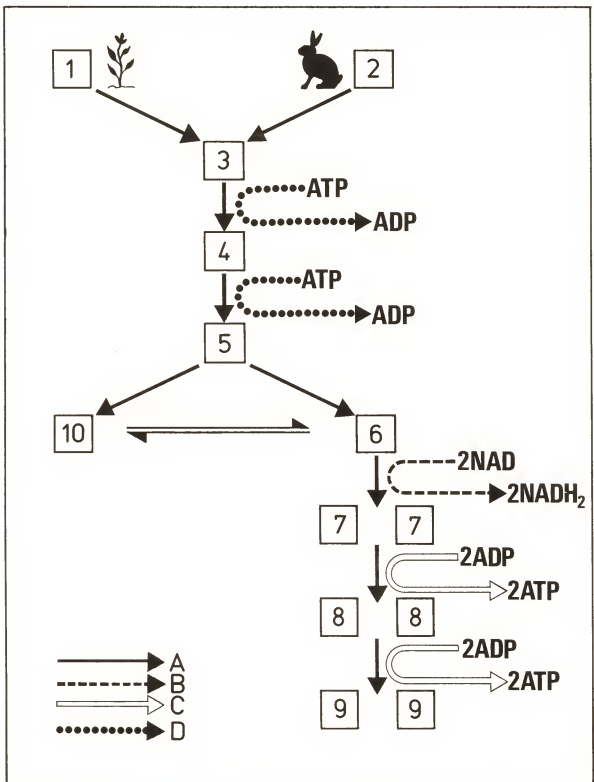
2 Pyruvic acid

3 Acetyl coenzyme A

4 Carbon dioxide

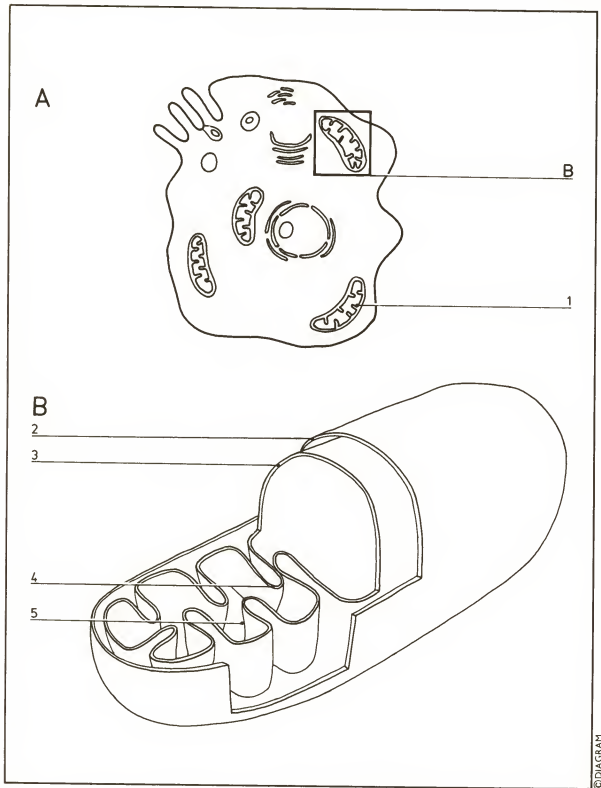
Glycolysis

01.048



Mitochondrion: structure 1

01.049

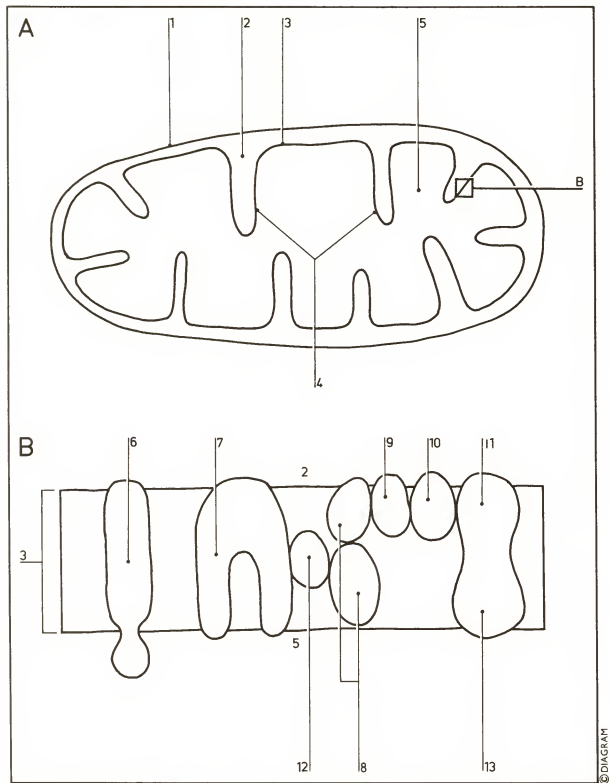


A Cell
B Mitochondrion – part-sectioned

- 1 Mitochondrion
- 2 Outer membrane
- 3 Inner membrane
- 4 Cristae
- 5 Matrix (M compartment)

Mitochondrion: structure 2

01.050



A Mitochondrion – section

B Detail of inner membrane

1 Outer membrane
2 Outer (O) compartment
3 Inner membrane

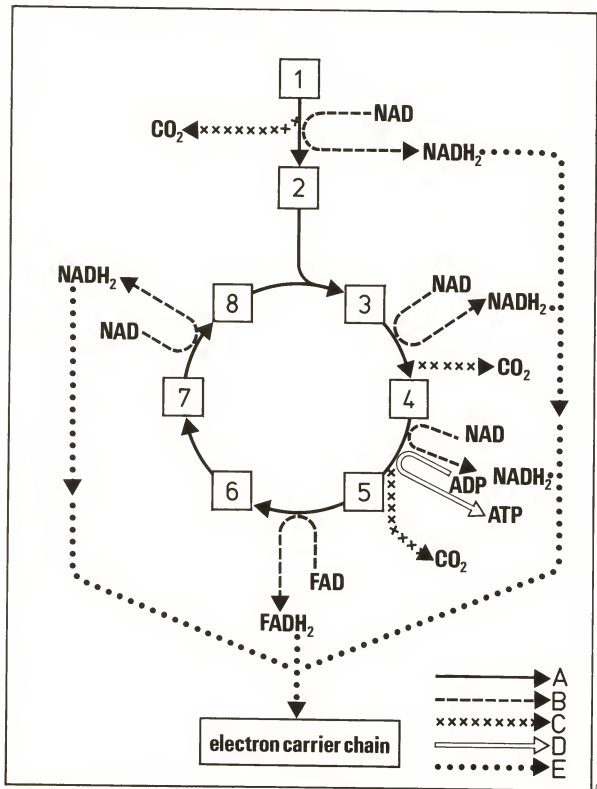
4 Cristae
5 Matrix (M) compartment
6 ATPase
7 Flavinoprotein
8 Cytochrome b
9 Cytochrome c₁
10 Cytochrome c
11 Cytochrome a

12 Coenzyme Q
13 Cytochrome a₃

© DIAGRAM

Krebs (citric acid) cycle

01.051

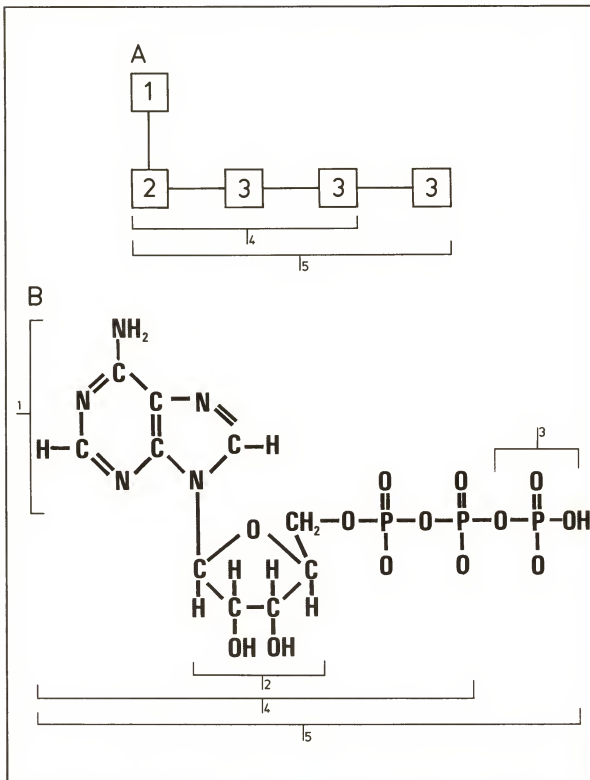


- A Reactions of Krebs cycle
B Removal of hydrogen
C Removal of carbon dioxide
D ATP produced by substrate-level phosphorylation
E Hydrogen transferred by acceptor to electron carrier chain

- 1 Pyruvic acid (3C)
2 Acetyl coenzyme A (2C)
3 Citric acid (6C)
4 α -ketoglutaric acid (5C)
5 Succinic acid (4C)
6 Fumaric acid (4C)
7 Malic acid (4C)
8 Oxaloacetic acid (4C)

ATP structure

01.052

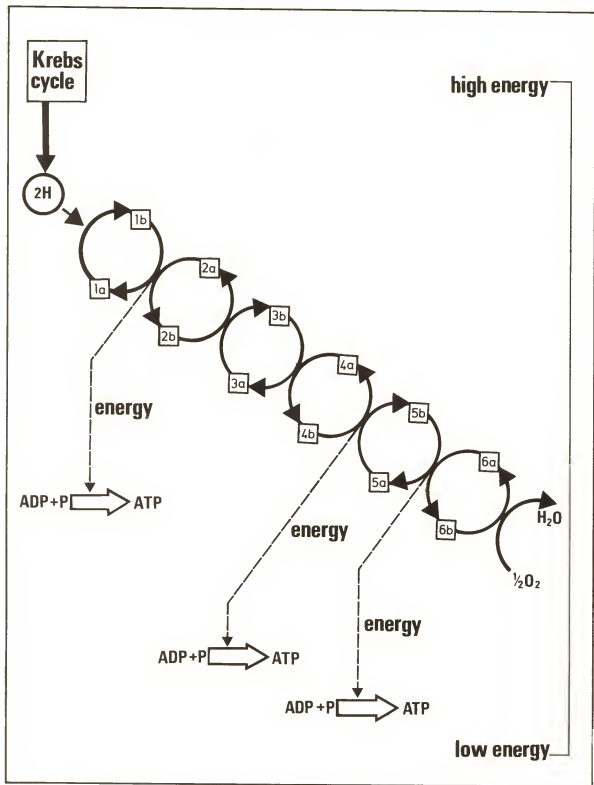


A Simplified structure
B Molecular structure

- 1 Adenine
- 2 Ribose
- 3 Phosphate
- 4 Adenosine diphosphate (ADP)
- 5 Adenosine triphosphate (ATP)

Electron carrier chain

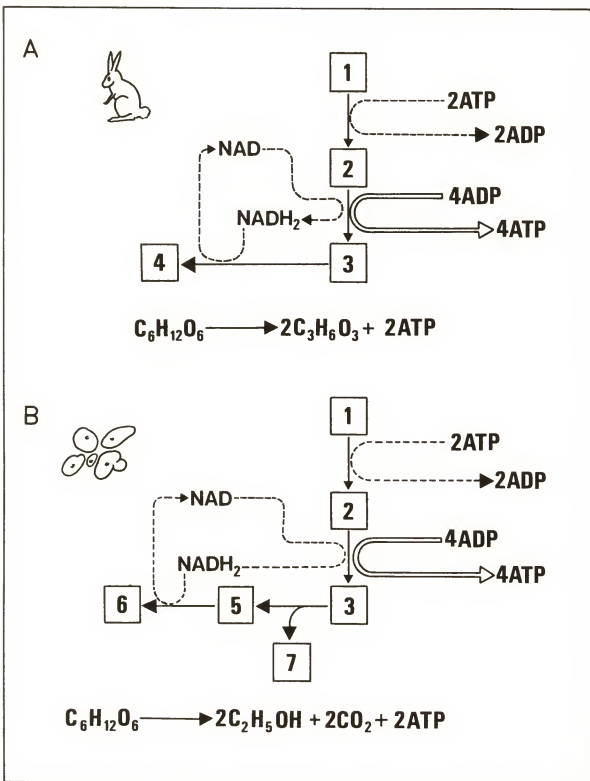
01.053



- | | |
|----------------|----------------------|
| 1 NAD | 4 Cytochrome b |
| 1a Oxidized | 4a Oxidized |
| 1b Reduced | 4b Reduced |
| 2 Flavoprotein | 5 Cytochrome c |
| 2a Oxidized | 5a Oxidized |
| 2b Reduced | 5b Reduced |
| 3 Coenzyme Q | 6 Cytochrome oxidase |
| 3a Oxidized | 6a Oxidized |
| 3b Reduced | 6b Reduced |

Anaerobic respiration

01.054

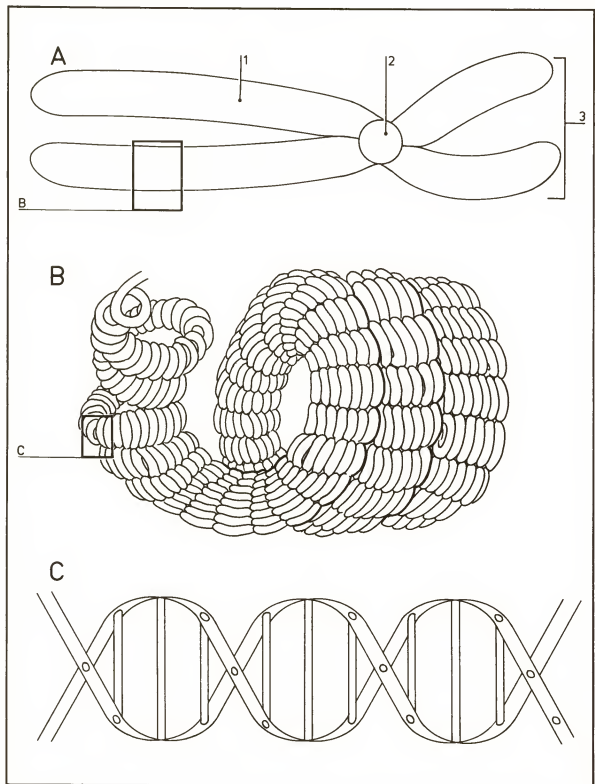


A Lactic acid fermentation in animals
B Alcoholic fermentation in yeast

- 1 Glucose
- 2 Fructose diphosphate
- 3 Pyruvic acid
- 4 Lactic acid
- 5 Acetaldehyde
- 6 Ethanol
- 7 Carbon dioxide

Chromosome structure

01.055



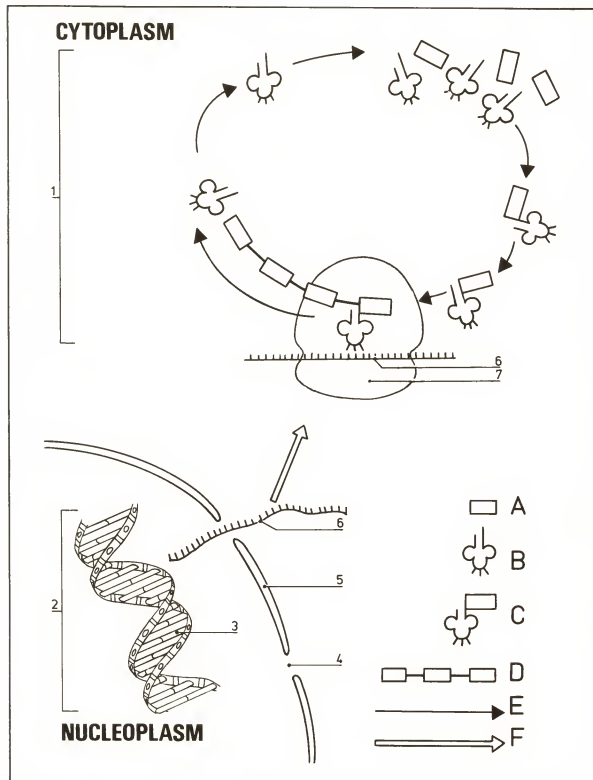
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- A Chromosome
- B Protein and DNA superhelix
- C One of many DNA double helices forming chromosome

- 1 Chromatid
- 2 Centromere
- 3 Chromosome

Summary of protein synthesis

01.056



A Free amino acid

B tRNA

C tRNA carrying amino acid

D Polypeptide chain

E Circulation of tRNA from cytoplasmic pool to ribosome to cytoplasmic pool

F Movement of mRNA from nucleus to cytoplasm

1 Translation

2 Transcription

3 DNA

4 Nuclear pore

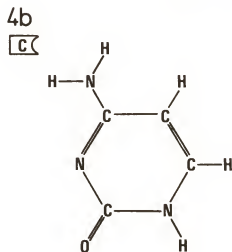
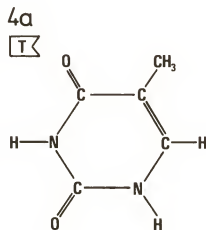
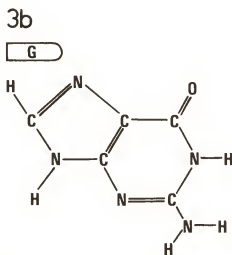
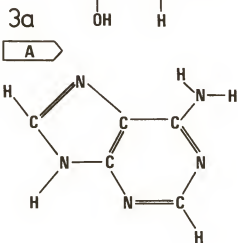
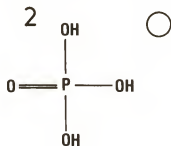
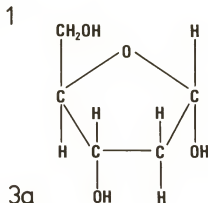
5 Nuclear membrane

6 mRNA

7 Ribosome

DNA components

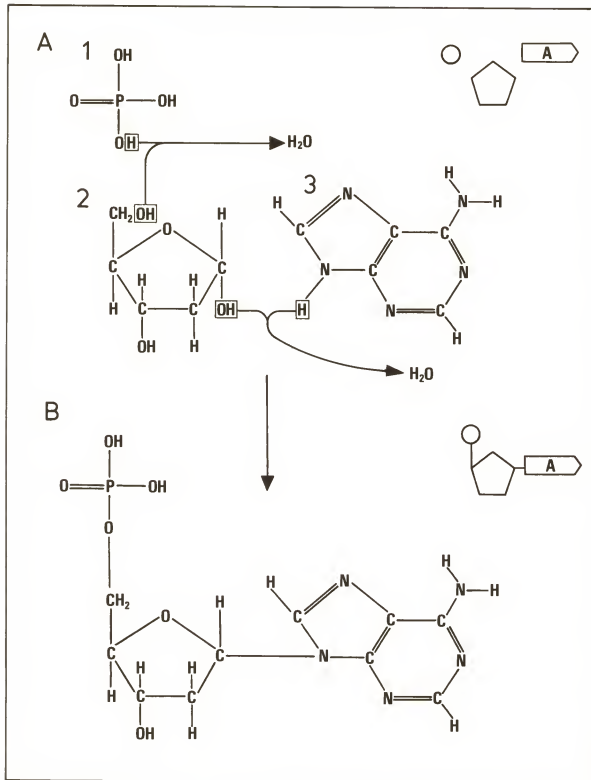
01.057



- 1 Deoxyribose
- 2 Phosphoric acid
- 3 Purine bases
- 3a Adenine
- 3b Guanine
- 4 Pyrimidine bases
- 4a Thymine
- 4b Cytosine

Nucleotide synthesis

01.058



DNA nucleotide synthesis

A Nucleotide components

B Nucleotide – adenosine monophosphate

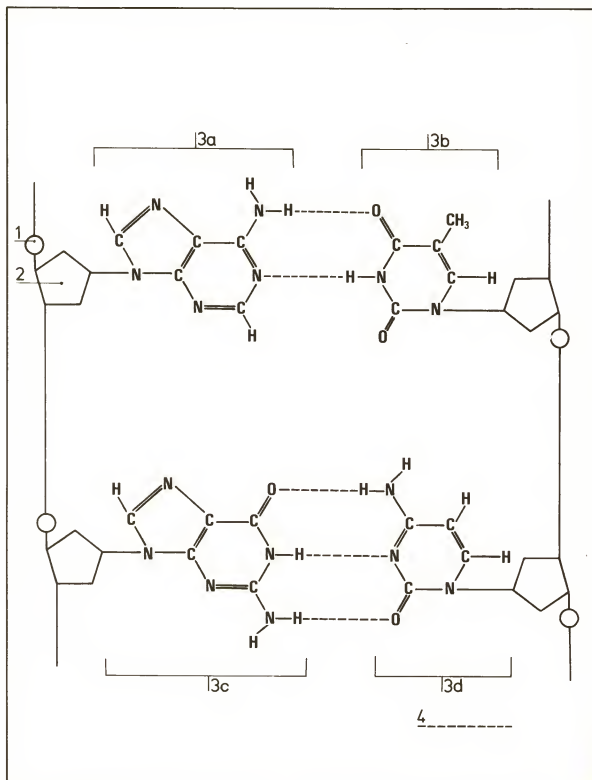
1 Phosphoric acid

2 Deoxyribose

3 Adenine

Base pairing

01.059



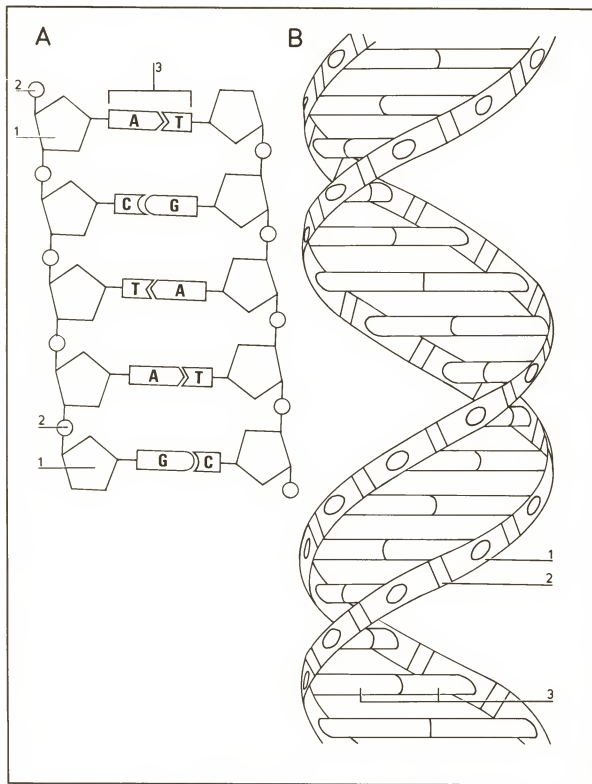
© DIAGRAM

Portion of DNA molecule

- 1 Phosphate
- 2 Deoxyribose
- 3 Bases
- 3a Adenine
- 3b Thymine
- 3c Guanine
- 3d Cytosine
- 4 Hydrogen bond

DNA structure

01.060

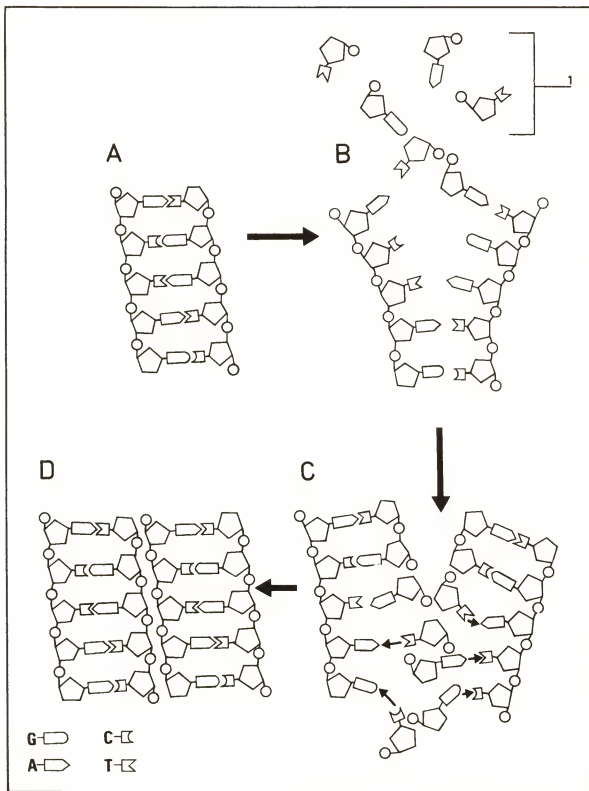


A Arrangement of nucleotides in DNA
B Schematicized double helix

- 1 Deoxyribose
2 Phosphate
3 Paired bases

DNA replication

01.061



A DNA molecule
B & C Enzymes and ATP break hydrogen bonds and
DNA chains separate. Free nucleotides find their
complementary bases.

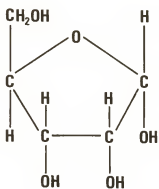
D Two new identical DNA molecules

1 Free nucleotides in nucleoplasm

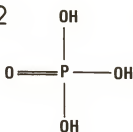
RNA components

01.062

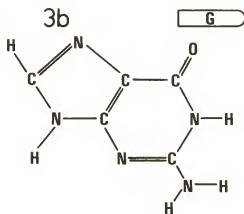
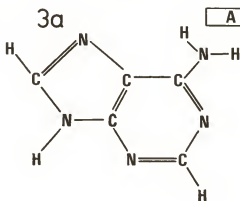
1



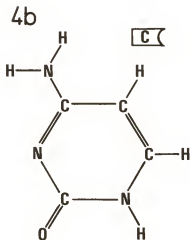
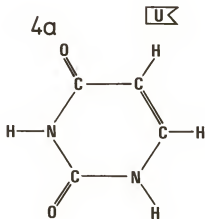
2



3



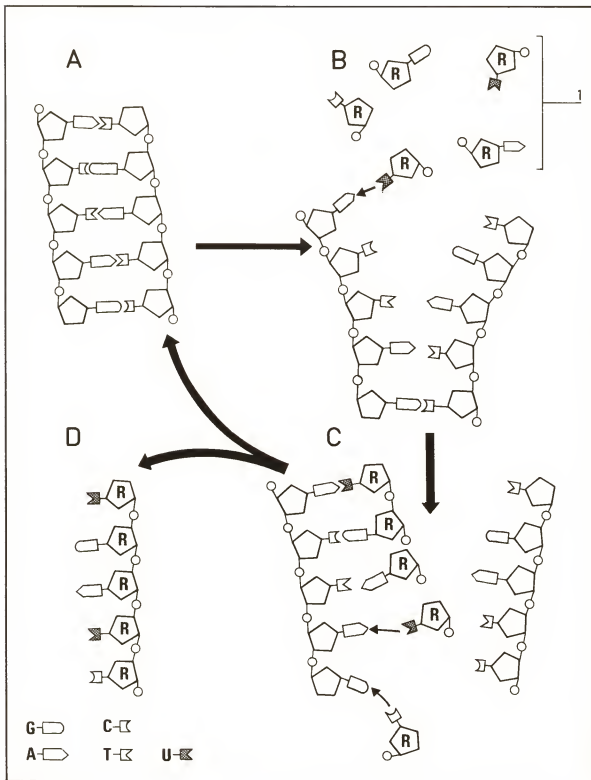
4



- 1 Ribose
- 2 Phosphoric acid
- 3 Purine bases
- 3a Adenine
- 3b Guanine
- 4 Pyrimidine bases
- 4a Uracil
- 4b Cytosine

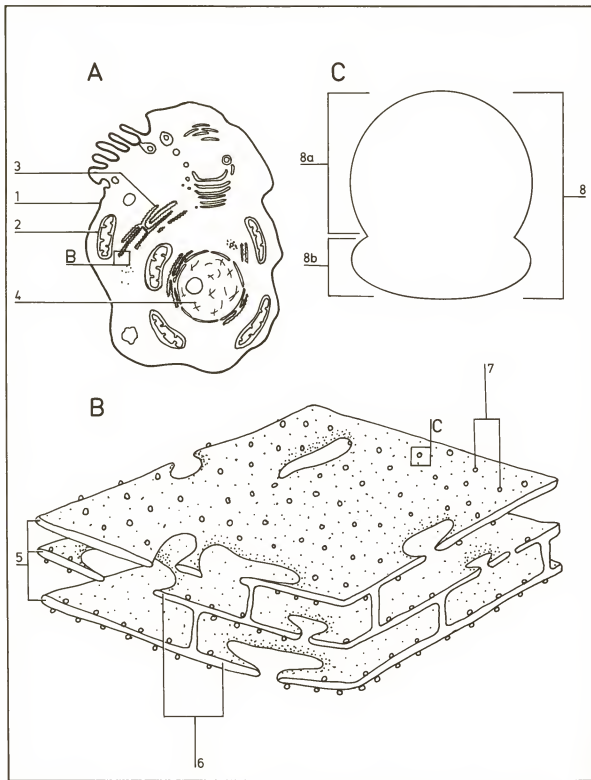
DNA transcription

01.063



Rough endoplasmic reticulum: structure

01.064



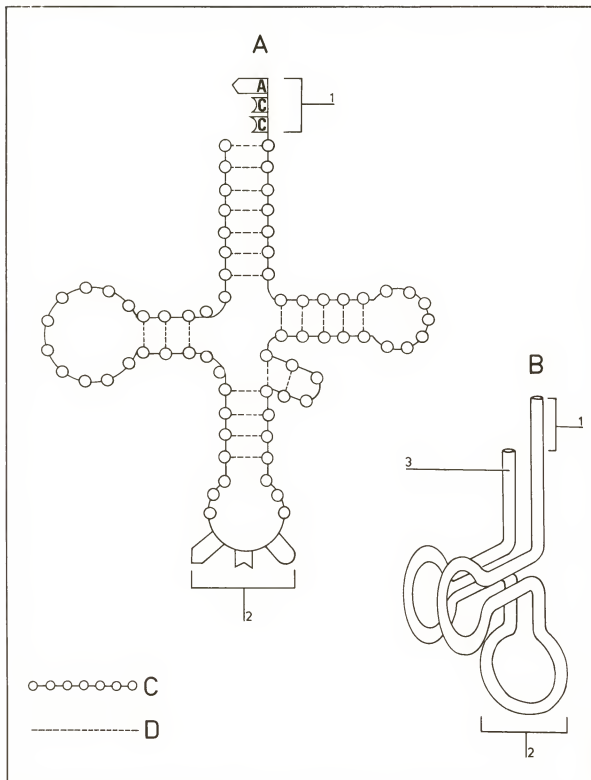
A Animal cell
B Schematic structure of rough endoplasmic reticulum
C Ribosome

1 Cell membrane
2 Mitochondrion
3 Rough endoplasmic reticulum
4 Nucleus

5 Lamellae (each made up of two membranes)
6 Cavities
7 Ribosomes
8 Ribosomal subunits containing ribosomal RNA (rRNA)
8a Large subunit
8b Small subunit

Transfer RNA

01.065

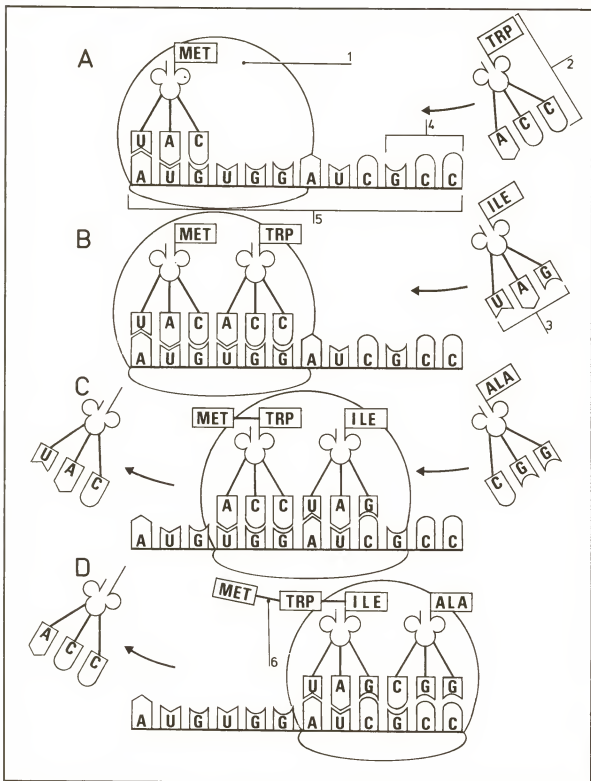


- A** Cloverleaf model of tyrosine transfer RNA (tRNA)
B Three dimensional representation of tRNA
C Nucleotide chain
D Hydrogen bond

- 1 Amino acid binding site
 2 Anticodon (mRNA binding site)
 3 Nucleotide chain

Messenger RNA translation

01.066



mRNA translation in the cytoplasm

- tRNA with anticodon UAC and carrying methionine binds to correct codon AUG on mRNA.
- tRNA molecule with the correct anticodon binds to the codon at the second site. It carries tryptophan.
- A peptide bond forms between methionine and tryptophan. The first tRNA molecule returns to the cytoplasm to pick up another methionine

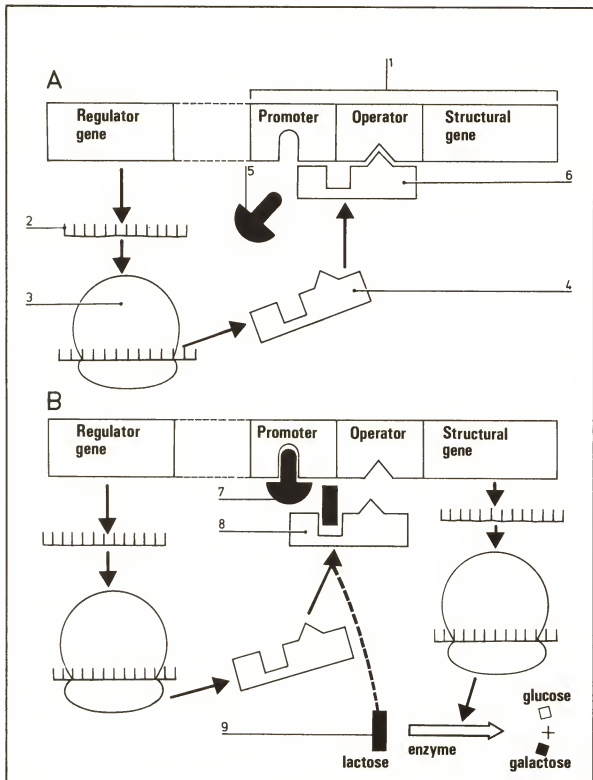
molecule. The ribosome shifts and a third tRNA molecule binds to mRNA.

- The process is repeated.

- Ribosome
- tRNA
- Anticodon
- Codon
- mRNA
- Peptide bond

Gene control

01.067



©DIAGRAM

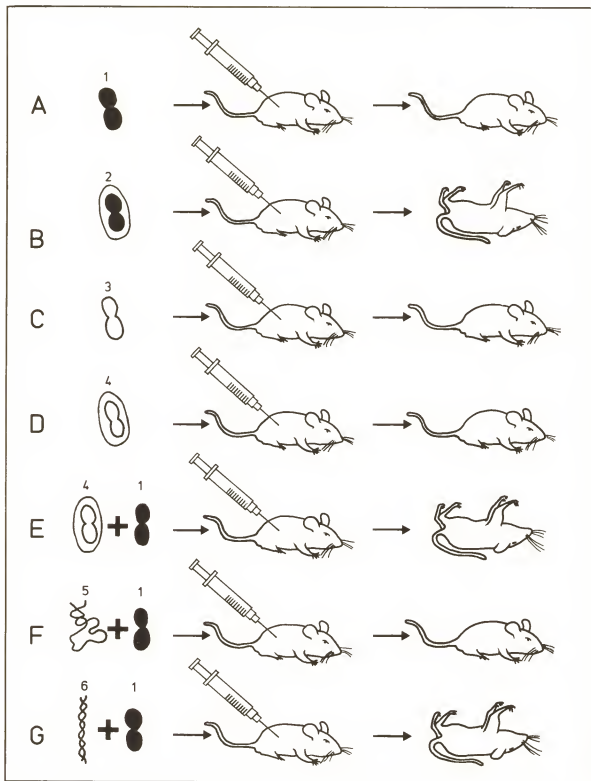
Gene induction – β galactosidase in *Escherichia coli*
A Operon repressed (structural gene switched off)
B Operon derepressed (structural gene switched on)

- 1 Operon
- 2 mRNA
- 3 Ribosome
- 4 Active repressor
- 5 RNA polymerase

- 6 Repressor bound to operator blocking RNA polymerase binding site
- 7 RNA polymerase bound to promoter
- 8 Repressor inactivated by inducer
- 9 Inducer (lactose)

Transformation

01.068



©DIAGRAM

Genetic transformation of pneumonia bacteria. The dead mice (B, E, G) had living S-type *Pneumococcus* in the bloodstream.

A – E Experiments of Griffiths, 1928

F & G Experiments of Avery et al 1944

4 Heat-killed S-type *Pneumococcus*

5 Protein from S-type *Pneumococcus*

6 DNA from S-type *Pneumococcus*

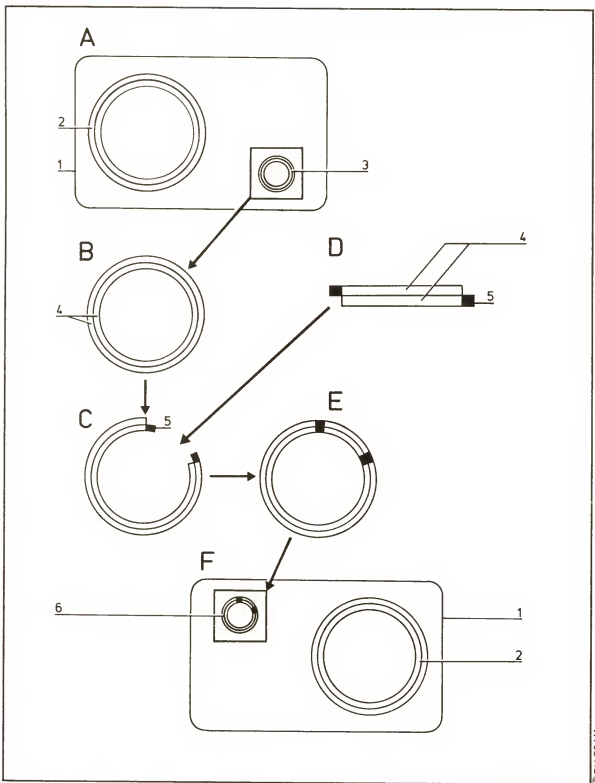
1 Rough (R-type) non-virulent *Pneumococcus*

2 Smooth (S-type) virulent *Pneumococcus*

3 Heat-killed R-type *Pneumococcus*

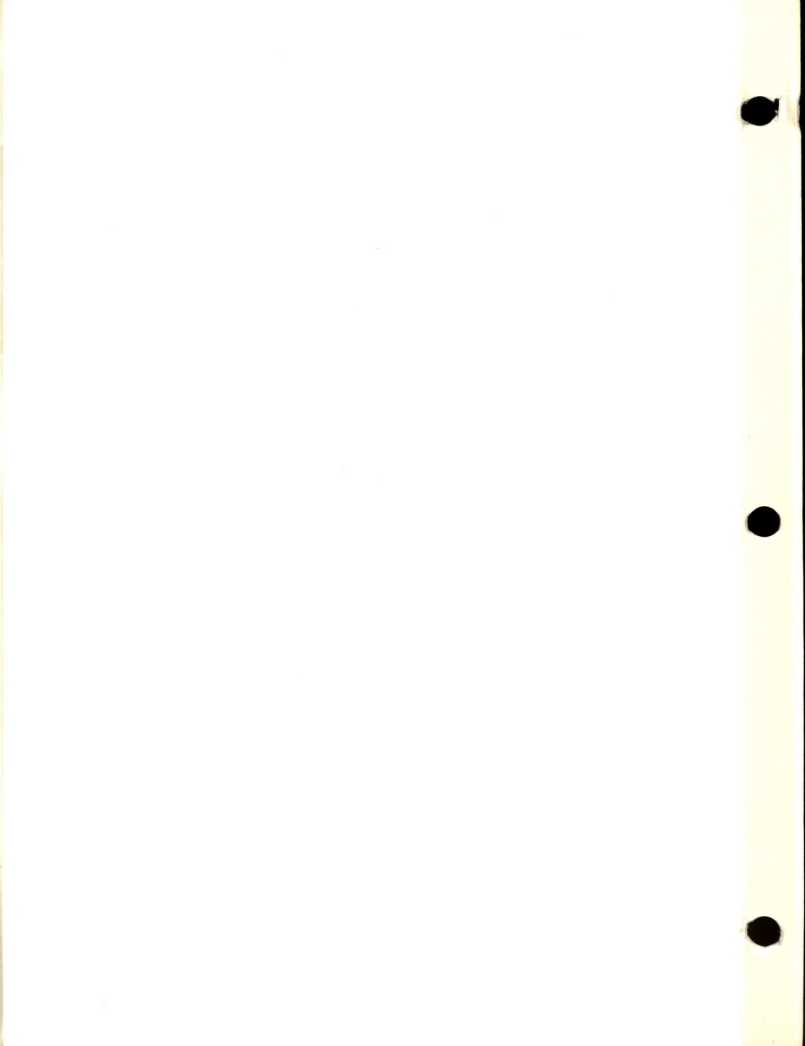
Genetic engineering

01.069



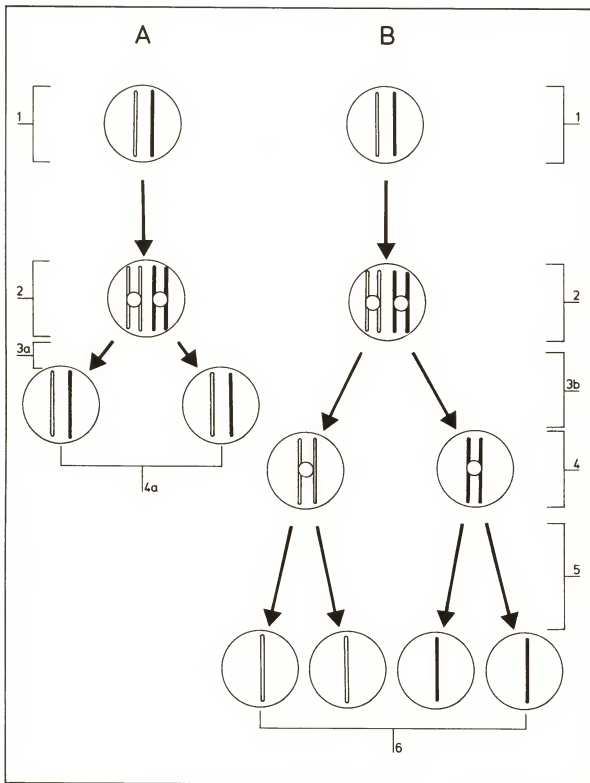
- A** Bacterium
B Plasmid
C Cleavage (plasmid cleaved by restriction endonuclease)
D Foreign DNA
E Annealing (plasmid and foreign DNA join at their sticky ends)
F Transformation (bacterium picks up modified plasmid)

- 1** Bacterium
2 Bacterial DNA
3 Plasmid
4 Complementary strands of DNA
5 Sticky end
6 Reconstituted plasmid acting as vector for foreign DNA



Cell division

02.001



© DIAGRAM

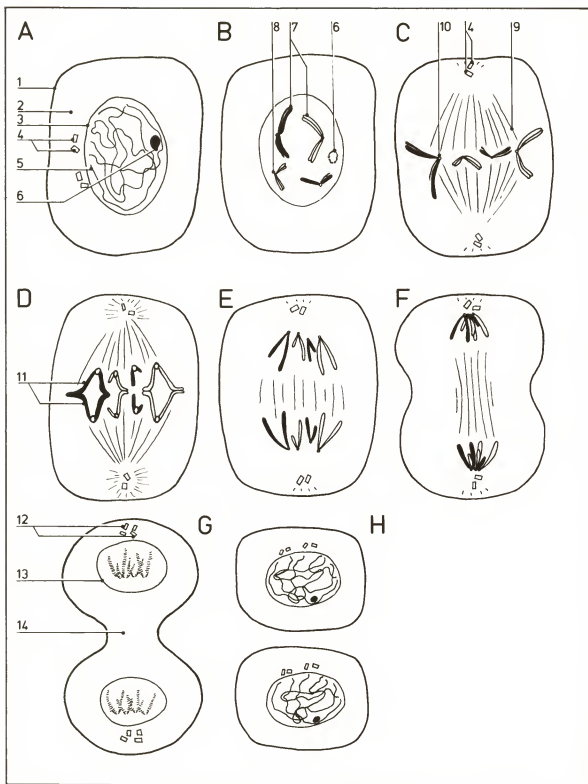
A Mitosis
B Meiosis

- 1 Diploid parental cell with one pair of homologous chromosomes
- 2 Chromosomes duplicate to form pairs of chromatids
- 3 Cell division
- 3a Mitotic division
- 3b First meiotic division

- 4 Daughter cells
- 4a Diploid, identical to parental cell
- 4b Haploid, not identical to parental cell
- 5 Second meiotic division
- 6 Haploid gametes

Mitosis

02.002

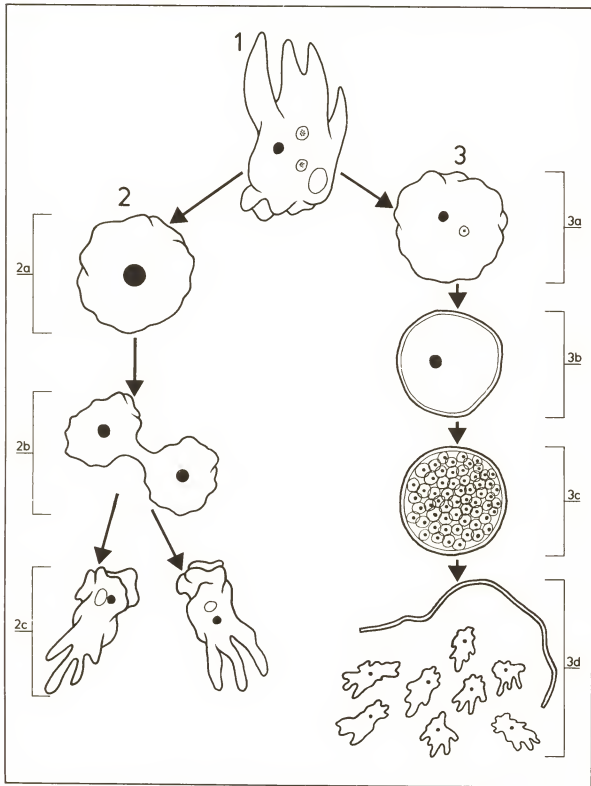


©DIAGRAM

- | | | |
|-------------------|--------------------------|-----------------------------|
| A Interphase | 2 Cytoplasm | to spindle equator |
| B Prophase | 3 Nuclear membrane | 11 Chromatids separate |
| C Metaphase | 4 Centrioles | 12 Centrioles replicate |
| D Early anaphase | 5 Chromatin thread | 13 Nuclear membrane reforms |
| E Late anaphase | 6 Nucleolus | 14 Cytoplasm divides |
| F Early telophase | 7 Homologous chromosomes | |
| G Late telophase | 8 Centromere | |
| H Daughter cells | 9 Spindle fiber | |
| 1 Cell membrane | 10 Centromere attached | |

Asexual reproduction 1: fission

02.003

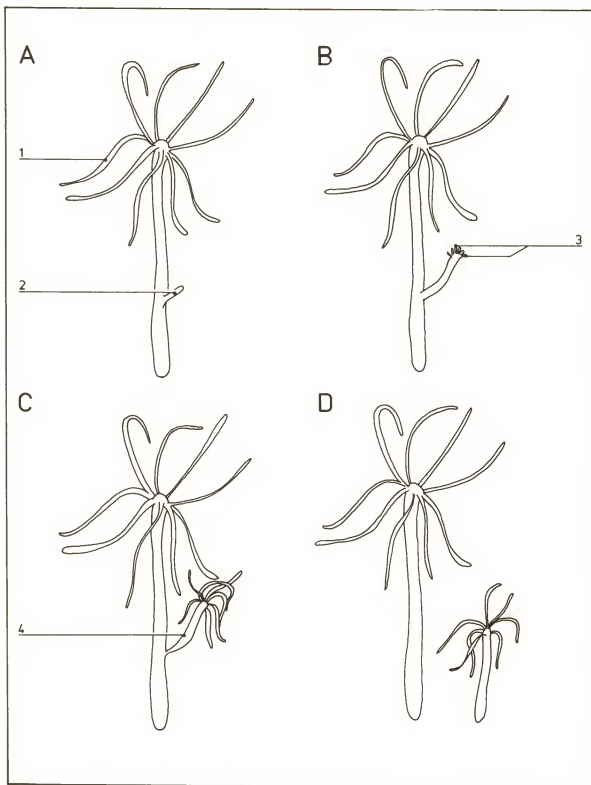


- 1 Fully grown *Amoeba*
 2 Binary fission
 2a *Amoeba* withdraws its pseudopodia, and its nucleus divides by mitosis
 2b Daughter nuclei separate, and cytoplasm constricts
 2c Daughter amoebae
 3 Multiple fission
 3a *Amoeba* withdraws its pseudopodia
 3b *Amoeba* secretes a cyst wall
 3c *Amoeba* divides many times by mitosis

3d Under favorable conditions the cyst ruptures, releasing daughter amoebae

Asexual reproduction 2: budding

02.004

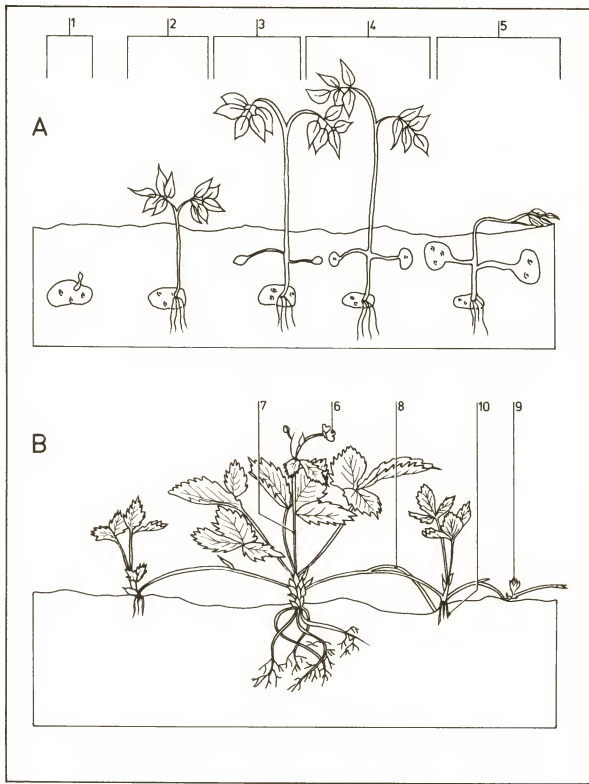


- A Mitotic division in the body wall of *Hydra* produces a bud
B The bud develops tentacles
C The bud becomes fully developed and detaches itself
D Two separated *Hydra*

- 1 Tentacle
2 Bud
3 Tentacles developing on bud
4 Daughter *Hydra* about to detach

Asexual reproduction 3: vegetative propagation

02.005



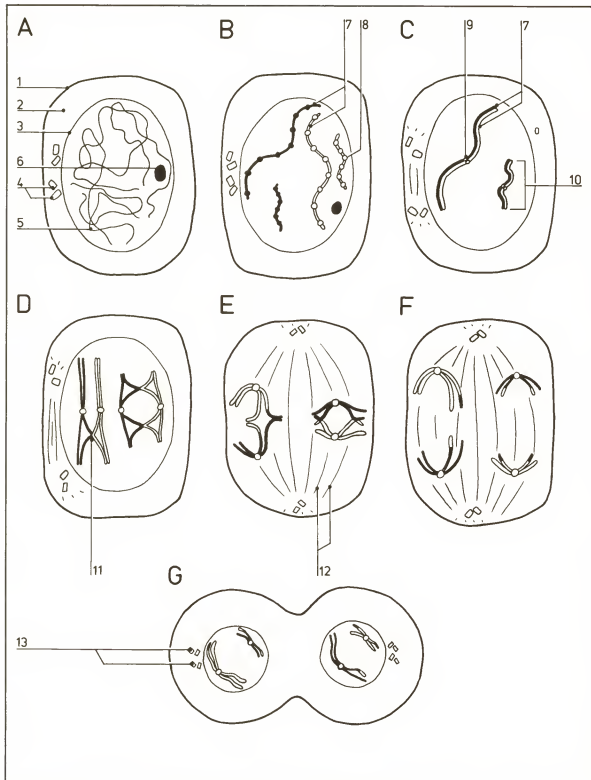
A Potato
B Strawberry

7 Parent plant
8 Runner
9 New plant developing from lateral bud of runner
10 Adventitious root

- 1 Shoot grows from lateral bud
- 2 Shoot forms leaves; roots grow
- 3 Side stems grow out and swell up into tubers
- 4 Food made in the leaves is stored in the tubers
- 5 Leaves, stem and old tuber die, but new tubers remain dormant in soil
- 6 Flower reproduces seeds by sexual reproduction

Meiosis: first division

02.006

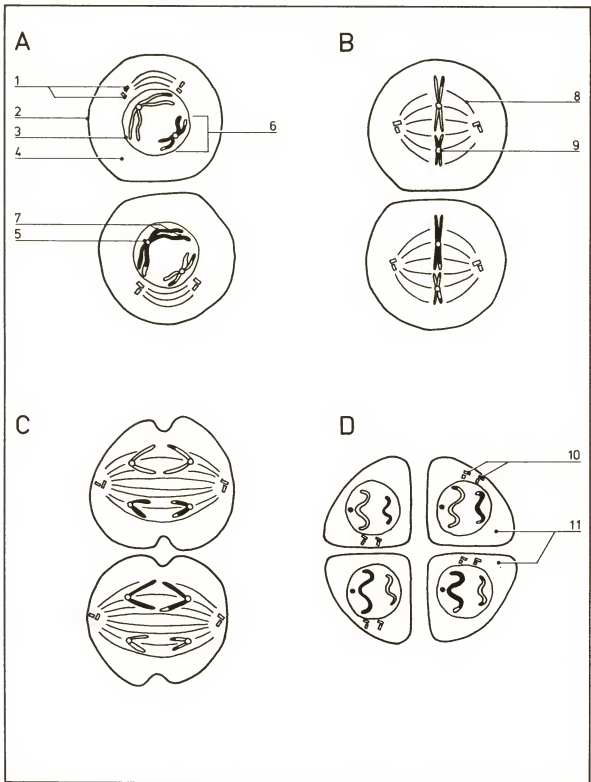


© DIAGRAM

- | | | |
|---------------------------|---------------------------------|--------------------------------|
| A Interphase | 3 Nuclear membrane | 12 Spindle fibers |
| B Early prophase I | 4 Centrioles | 13 Centrioles replicate |
| C Mid prophase I | 5 Chromatin thread | |
| D Late prophase I | 6 Nucleolus | |
| E Metaphase I | 7 Homologous chromosomes | |
| F Anaphase I | 8 Chromomeres | |
| G Telophase I | 9 Centromeres | |
| 1 Cell membrane | 10 Bivalent | |
| 2 Cytoplasm | 11 Chiasma | |

Meiosis: second division

02.007



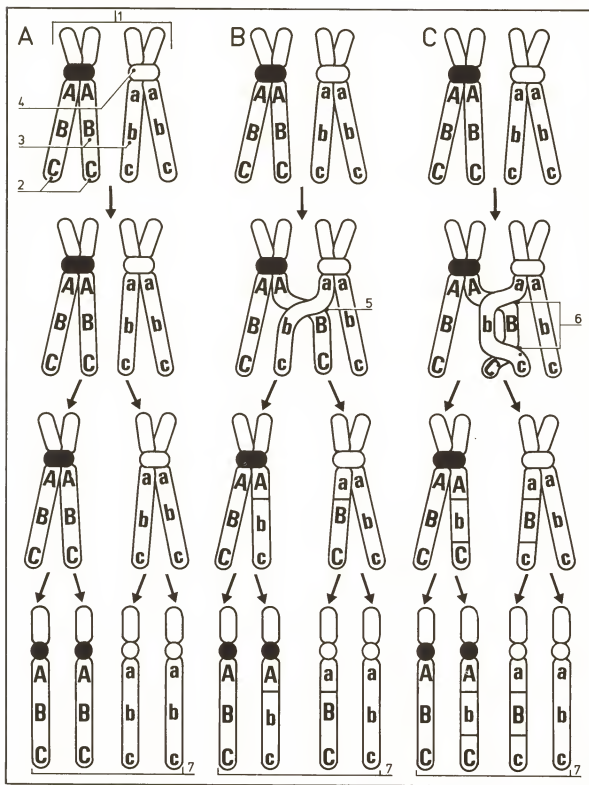
A Prophase II
B Metaphase II
C Anaphase II
D Telophase II

6 Chromosome
7 Chromatids
8 Spindle fiber
9 Centromere attached
to spindle equator
10 Centrioles replicate
11 Haploid daughter cells

1 Centrioles
2 Cell membrane
3 Nuclear membrane
4 Cytoplasm
5 Centromere

Crossing over and genetic variation

02.008



A No crossing over
B Single crossing over
C Double crossing over

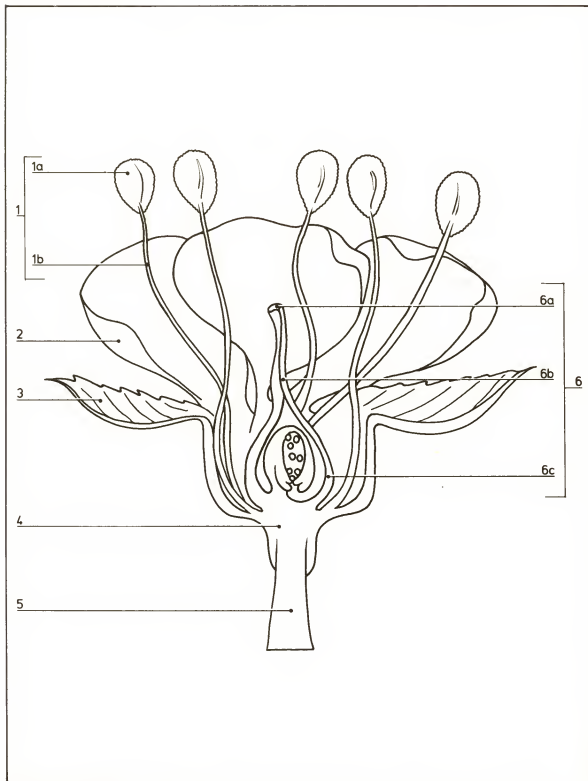
5 Chiasma
6 Chiasmata
7 Chromosome variation
in the four haploid
gametes

1 Homologous
chromosomes
2 Chromatids
3 Alleles
4 Centromere

© DIAGRAM

Flower structure

02.009



Vertical section through
flower

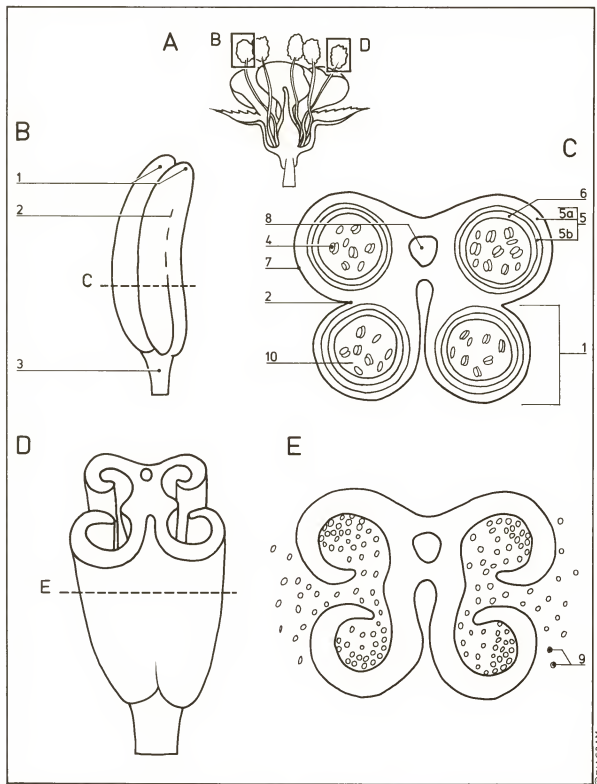
- 1 Stamen
- 1a Anther
- 1b Filament
- 2 Petal
- 3 Sepal
- 4 Receptacle
- 5 Flower stalk

- 6 Pistil
- 6a Stigma
- 6b Style
- 6c Ovary

©DIAGRAM

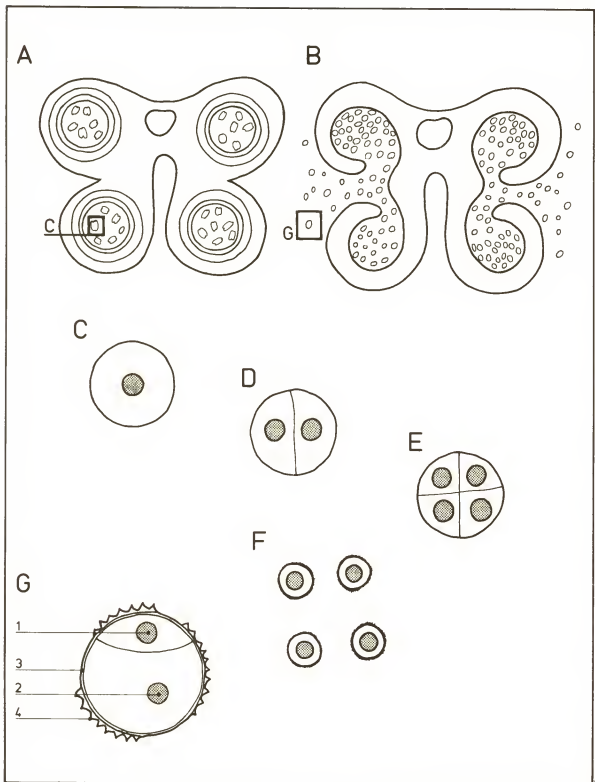
Mature stamen

02.010



Pollen formation

02.011



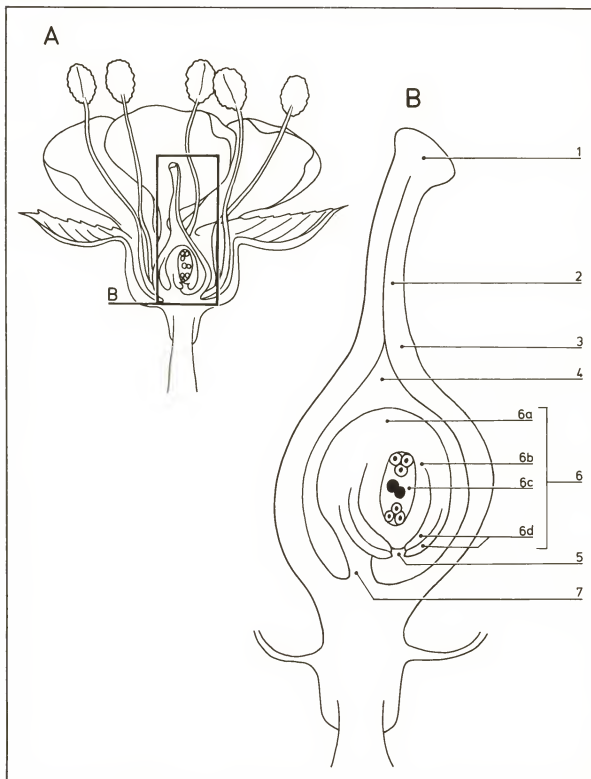
© DIAGRAM

- A Anther before dehiscence – transverse section
 B Anther after dehiscence – transverse section
 C Microspore mother cell
 D First meiotic division produces two cells
 E Second meiotic division produces tetrad of haploid microspores (pollen grains)
 F Pollen grains
 G Detail of pollen grain (microspore)

- 1 Generative nucleus
 2 Tube nucleus
 3 Intine
 4 Exine

Mature pistil

02.012

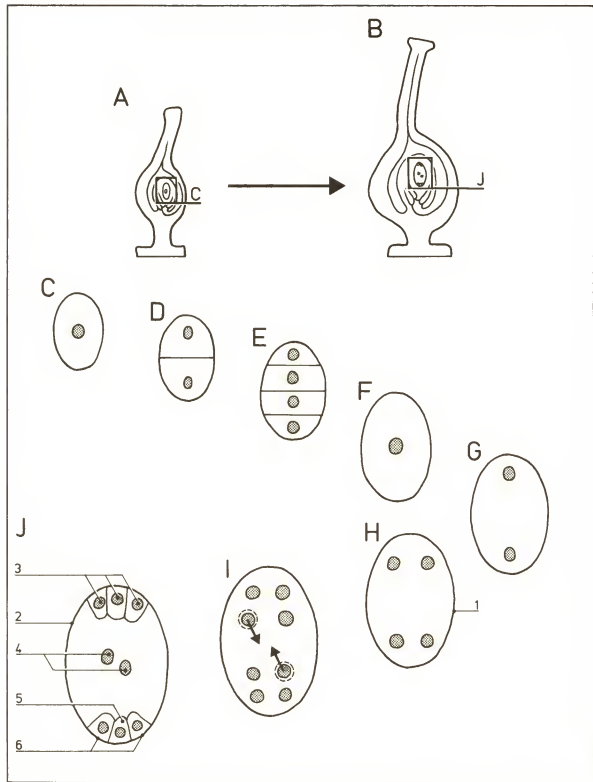


©DIAGRAM

- | | |
|---|-----------------------|
| A Flower – vertical section | 5 Micropyle |
| B Mature pistil – vertical section | 6 Ovule |
| 1 Stigma | 6a Chalaza |
| 2 Style | 6b Nucellus |
| 3 Ovary wall | 6c Embryo sac |
| 4 Cavity of ovary | 6d Integuments |
| | 7 Placenta |

Ovule formation

02.013



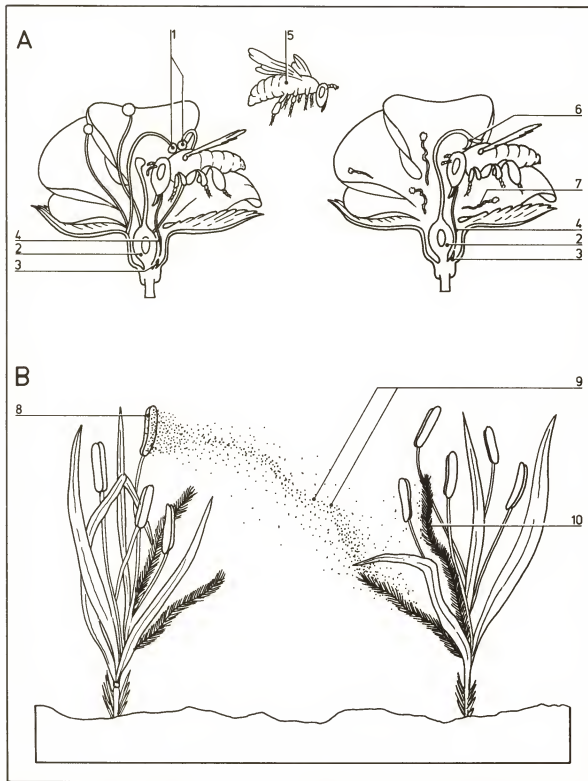
©DIAGRAM

- A Young carpel – vertical section
B Mature carpel – vertical section
C Diploid megaspore mother cell
D First meiotic division
E Second meiotic division
F Three cells die to leave haploid megaspore
G Mitotic division produces two nuclei
H Mitotic division produces four nuclei
I Mitotic division produces eight nuclei
J Mature embryo sac

- 1 Developing embryo sac
2 Embryo sac
3 Antipodal nuclei
4 Polar nuclei
5 Egg (oosphere)
6 Synergids

Pollination

02.014



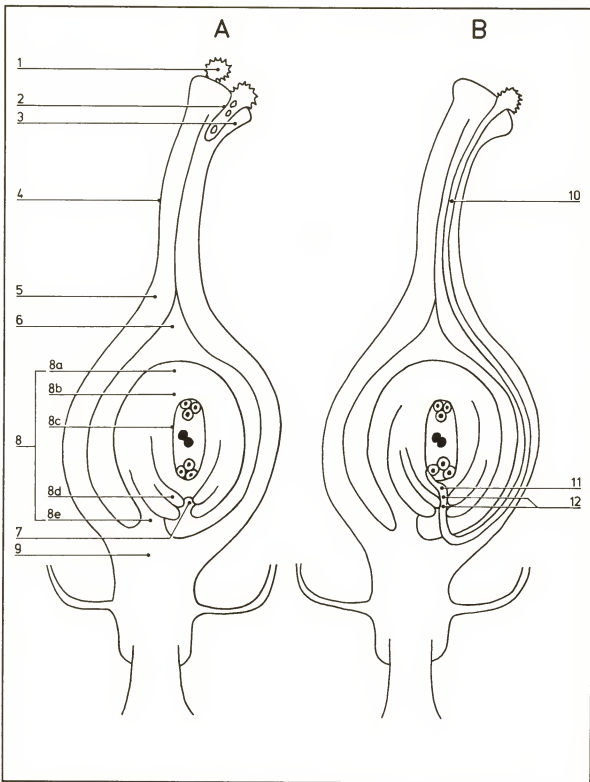
A Insect (entomophilous) pollination
B Wind (anemophilous) pollination

8 Pollen released from anthers hanging outside flower
9 Pollen
10 Large feathery stigma

- 1 Ripe anthers dust pollen onto back of bee
- 2 Ovary
- 3 Nectary
- 4 Proboscis
- 5 Bee flies to another flower
- 6 Ripe stigma touches back of bee
- 7 Dead stamen

Plant fertilization 1

02.015



A Pistil just after pollination – vertical section
B Pistil with pollen tube fully developed – vertical section

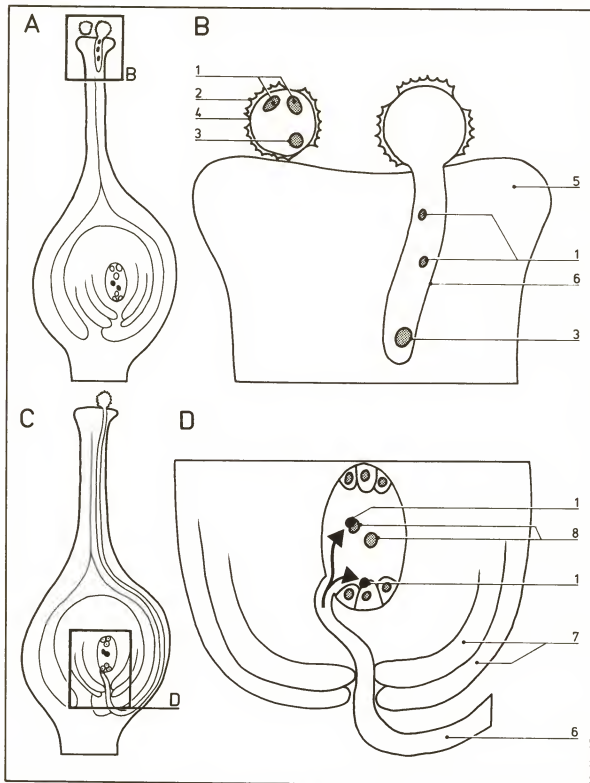
- 1 Pollen grain
- 2 Germinating pollen grain
- 3 Stigma
- 4 Style

- 5 Ovary wall
- 6 Cavity of ovary
- 7 Micropyle
- 8 Ovule
- 8a Chalaza
- 8b Nucellus
- 8c Embryo sac
- 8d Integuments
- 8e Funicle

- 9 Placenta
- 10 Pollen tube
- 11 Tube nucleus
- 12 ♂ gametes

Plant fertilization 2

02.016



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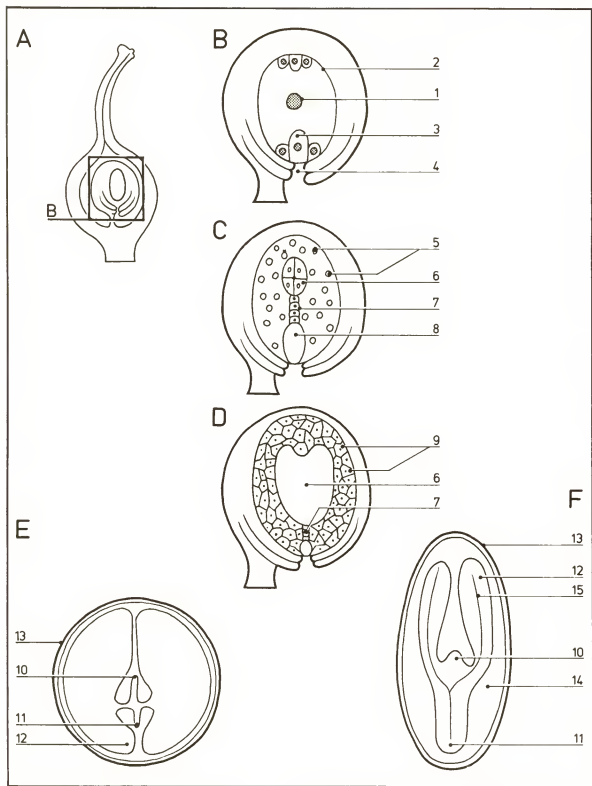
- A Pistil just after pollination - vertical section
B Pollen grains before and after pollination
C Pistil with pollen tube fully developed - vertical section
D Fertilization

- 1 ♂ gametes
2 Exine
3 Tube nucleus
4 Intine
5 Stigma
6 Pollen tube
7 Integuments
8 Polar nuclei

- 1 ♂ gametes
2 Exine
3 Tube nucleus

Seed development

02.017



- A** Pistil after fertilization – vertical section
B–D Development after fertilization
E Non-endospermic seed (pea) – longitudinal section
F Endospermic seed (castor oil) – longitudinal section

- 1 Endosperm nucleus
 (triploid)
 2 Embryosac
 3 Zygote (diploid)
 4 Micropyle

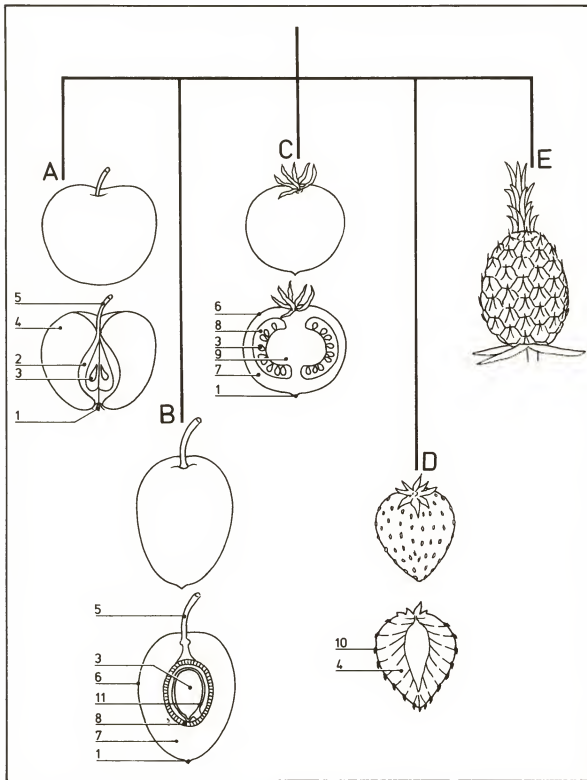
- 5 Endosperm nuclei
 6 Embryo
 7 Suspensor
 8 Basal cell
 9 Endosperm rich in
 stored food
 10 Plumule
 11 Radicle
 12 Cotyledon
 13 Testa

- 14 Endosperm
 15 Procambial strand

© DIAGRAM

Succulent fruits

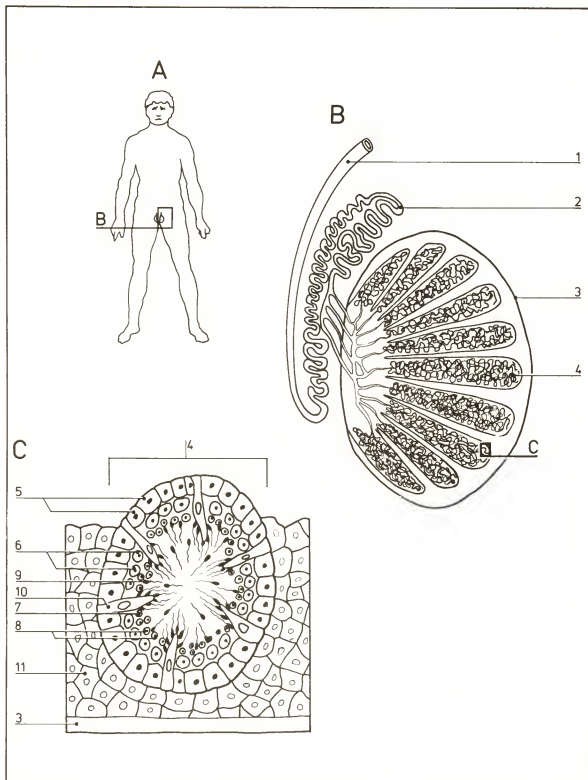
02.018



- A Pome (eg apple)
- B Drupe (eg plum)
- C Berry (eg tomato)
- D Aggregate (eg strawberry)
- E Multiple (eg pineapple)
- 1 Remains of flower
- 2 Pericarp
- 3 Seed
- 4 Swollen receptacle
- 5 Pedicel
- 6 Epicarp
- 7 Mesocarp
- 8 Endocarp
- 9 Placenta
- 10 Achene
- 11 Testa

Spermatogenesis 2

02.023



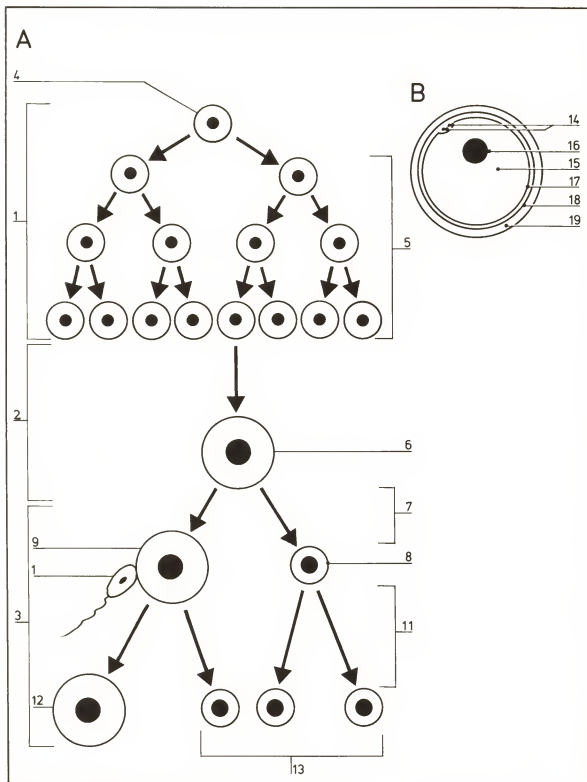
A Male human
B Testis – vertical section
C Seminiferous tubule –
transverse section

1 Vas deferens
2 Epididymis
3 Outer wall of testis
4 Seminiferous tubule –
cross section

5 Germ cells
6 Spermatogonia
7 Primary spermatocyte
8 Secondary
spermatocytes and
spermatids
9 Spermatozoon
10 Sertoli cell
11 Leydig cell

Oogenesis 1

02.024



© DIAGRAM

A Oogenesis - schematic
B Secondary oocyte prior to fertilization

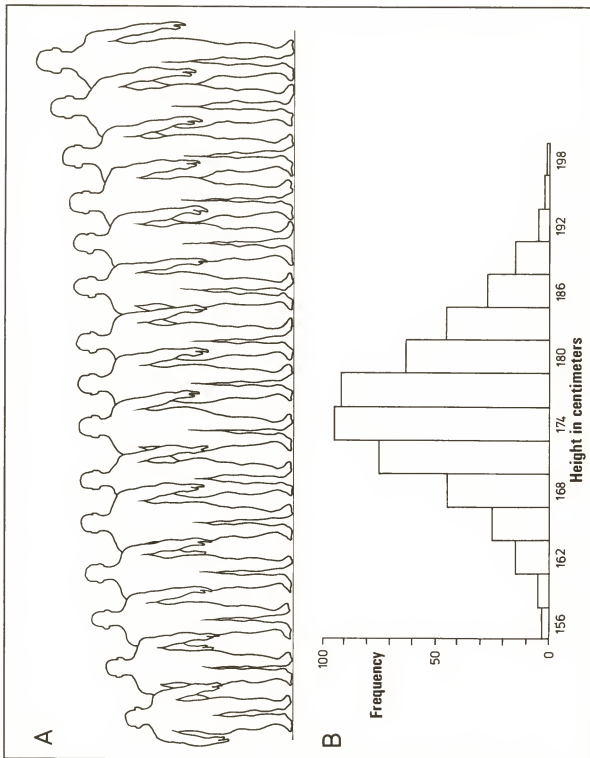
6 Primary oocyte
7 Meiosis I
8 First polar body
9 Secondary oocyte
10 Spermatozoon
11 Meiosis II
12 Ovum
13 Second polar bodies
14 Polar bodies
15 Cytoplasm

16 Nucleus
17 Plasma membrane
18 Vitelline membrane
19 Zona pellucida

1 Phase of multiplication by mitosis
2 Phase of growth
3 Phase of maturation
4 Germ cell
5 Oogonia

Continuous variation

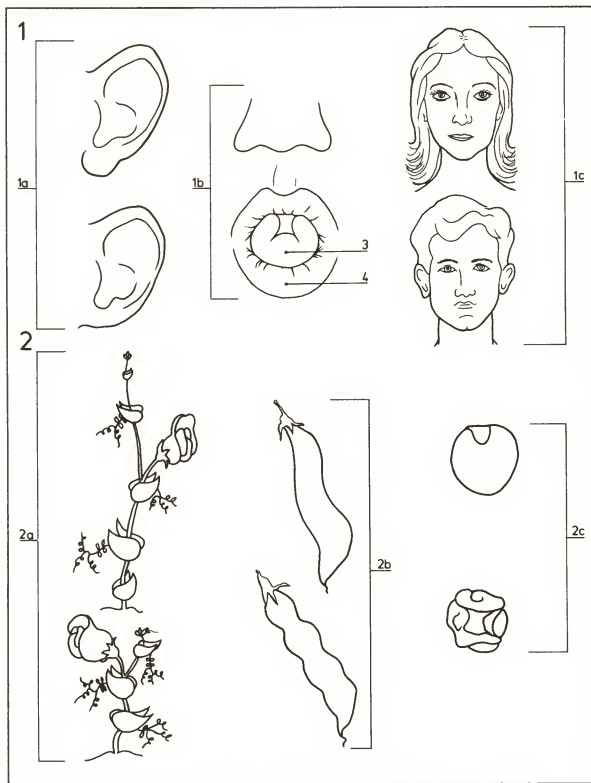
02.033



A Height in human males as an example of continuous variation
B Histogram showing variation in height in a group of human males

Discontinuous variation

02.034

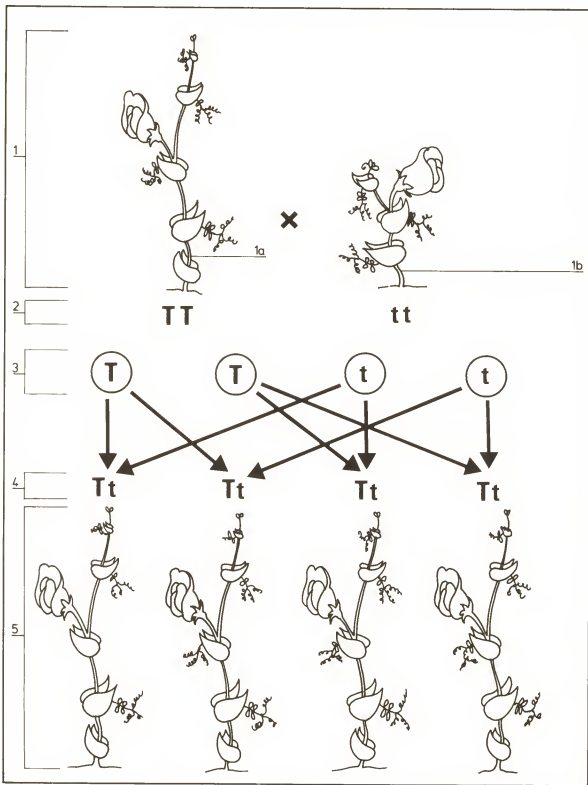


- 1 Discontinuous variation in humans
1a Free ear lobes and attached ear lobes
1b Tongue rolling
1c Female and male
2 Discontinuous variation in peas
2a Long and short stems
2b Smooth and constricted pods
2c Round and wrinkled seeds

- 3 Tongue
4 Lips

Peas: monohybrid cross 1

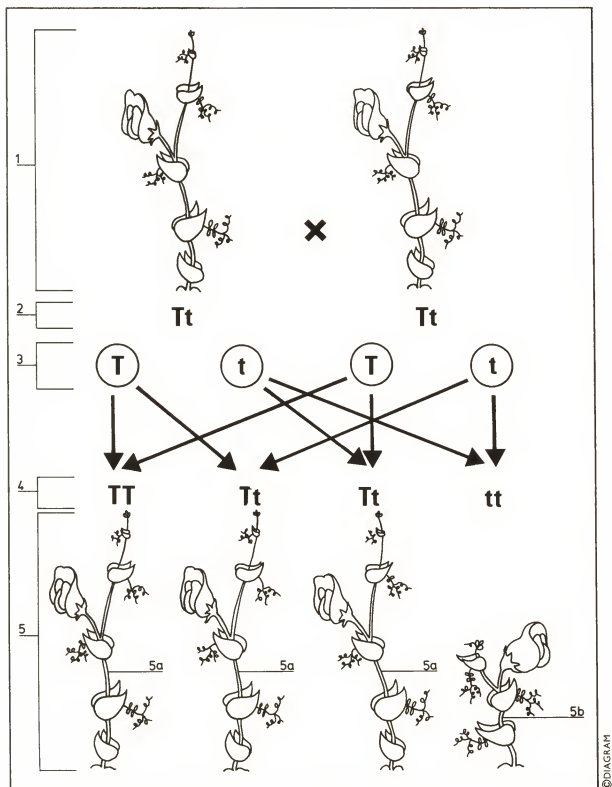
02.035



- 1 Parental phenotype
- 1a Long-stemmed (tall) plant
- 1b Short-stemmed (dwarf) plant
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 4 F₁ genotype
- 5 F₁ phenotype – all long-stemmed

Peas: monohybrid cross 2

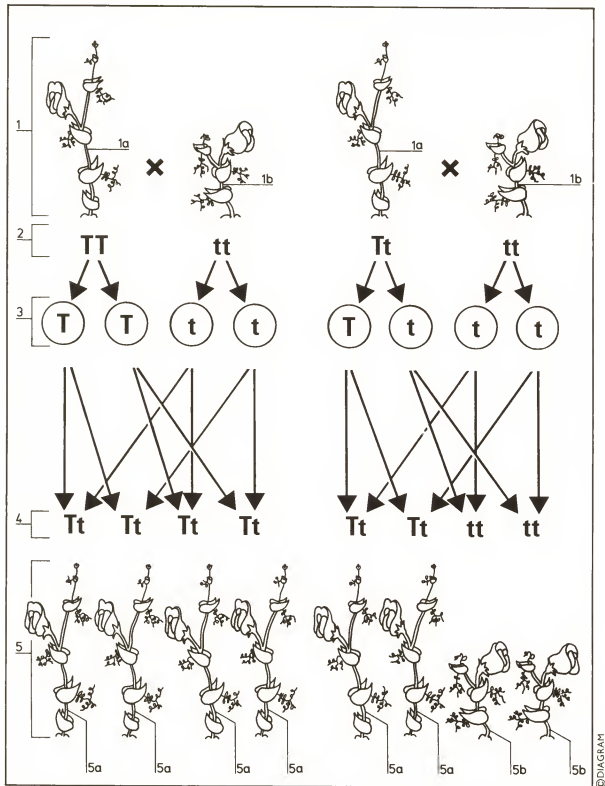
02.036



- 1 F_1 phenotype – both long-stemmed (tall)
- 2 F_1 genotype
- 3 Gametes produced by meiosis
- 4 F_2 genotype
- 5 F_2 phenotype
- 5a Long-stemmed
- 5b Short-stemmed

Peas: test cross

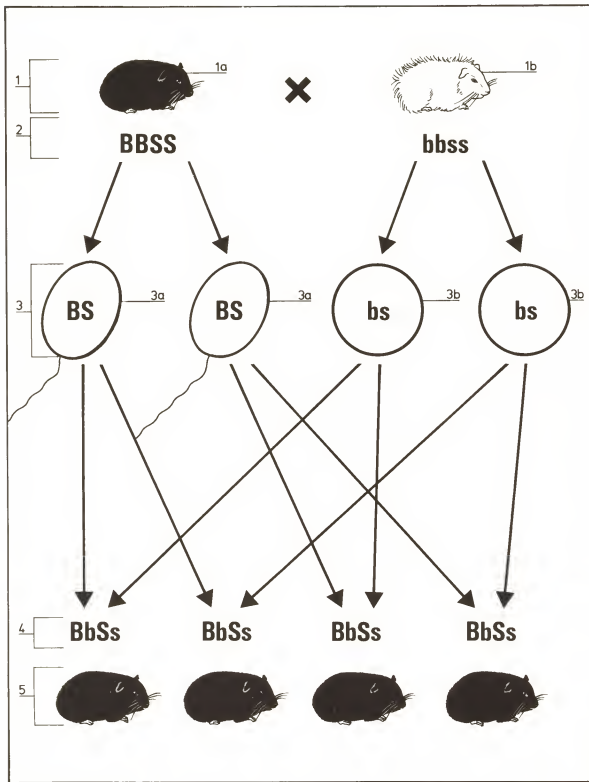
02.037



- 1 Parental phenotype
- 1a Long-stemmed (tall) plant
- 1b Short-stemmed (dwarf) plant
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 4 F₁ genotype
- 5 F₁ phenotype
- 5a Long-stemmed plant
- 5b Short-stemmed plant

Guinea pigs: dihybrid cross 1

02.038

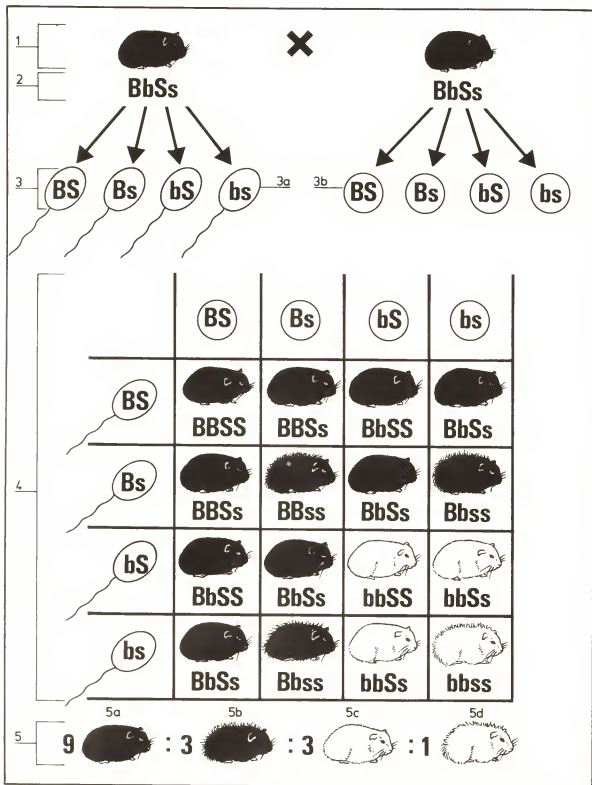


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- 1 Parental phenotypes
- 1a Black, short-haired
- 1b Brown, long-haired
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 3a Sperm
- 3b Ovum
- 4 F₁ genotype
- 5 F₁ phenotype – all black, short-haired

Guinea pigs: dihybrid cross 2

02.039



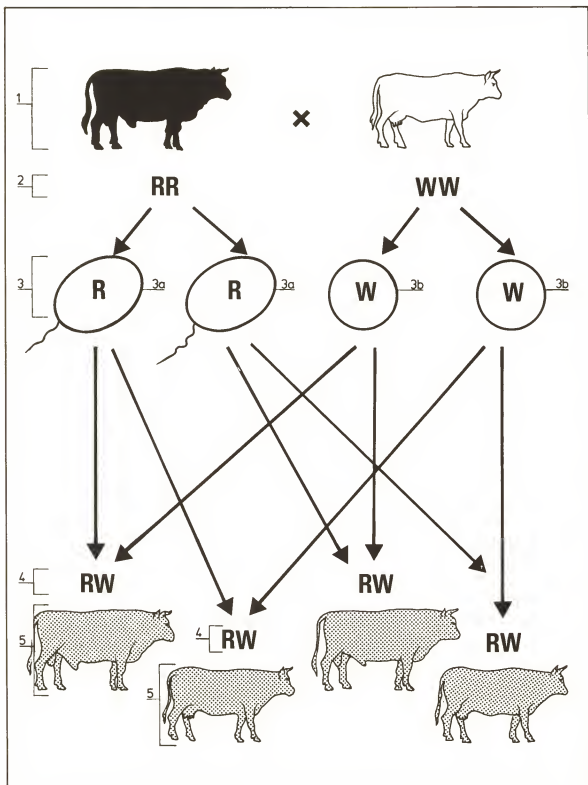
© DIAGRAM

- 1 F₁ phenotypes (black, short-haired)
- 2 F₁ genotypes
- 3 Gametes produced by meiosis
- 3a Sperm
- 3b Ova
- 4 Punnett square showing possible offspring in the F₂ generation
- 5 F₂ phenotype ratios
- 5a Black, short-haired

- 5b Black, long-haired
- 5c Brown, short-haired
- 5d Brown, long-haired

Shorthorn cattle: incomplete dominance 1

02.040



1 Parental phenotype – red male, white female

2 Parental genotype

3 Gametes produced by meiosis

3a Sperm

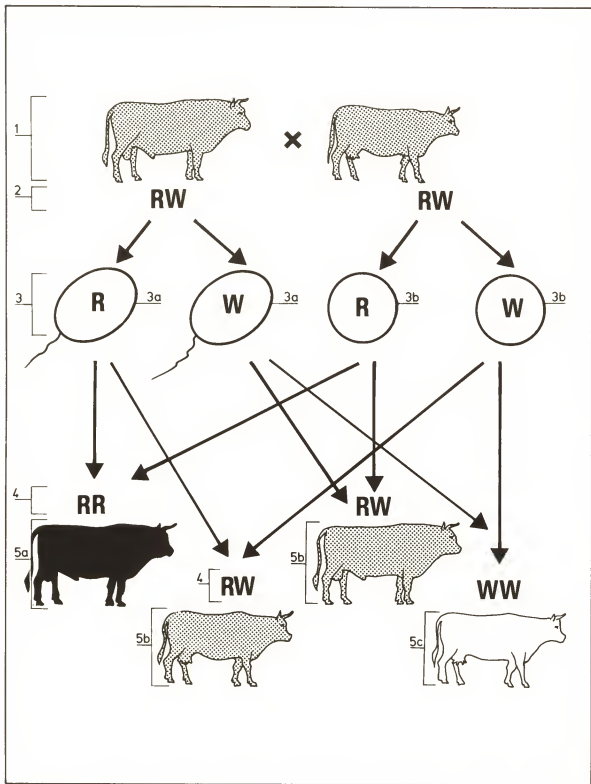
3b Ovum

4 F₁ genotype

5 F₁ phenotype – all roan

Shorthorn cattle: incomplete dominance 2

02.041

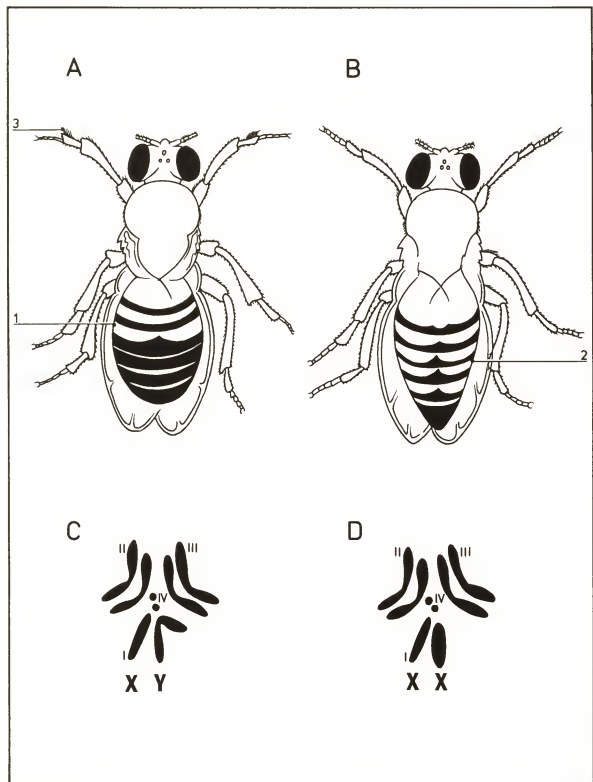


© DIAGRAM

- 1 F₁ phenotype – roan male, roan female
- 2 F₁ genotype
- 3 Gametes produced by meiosis
- 3a Sperm
- 3b Ovum
- 4 F₂ genotype
- 5 F₂ phenotype
- 5a Red
- 5b Roan
- 5c White

***Drosophila*: adult form and chromosomes**

02.042

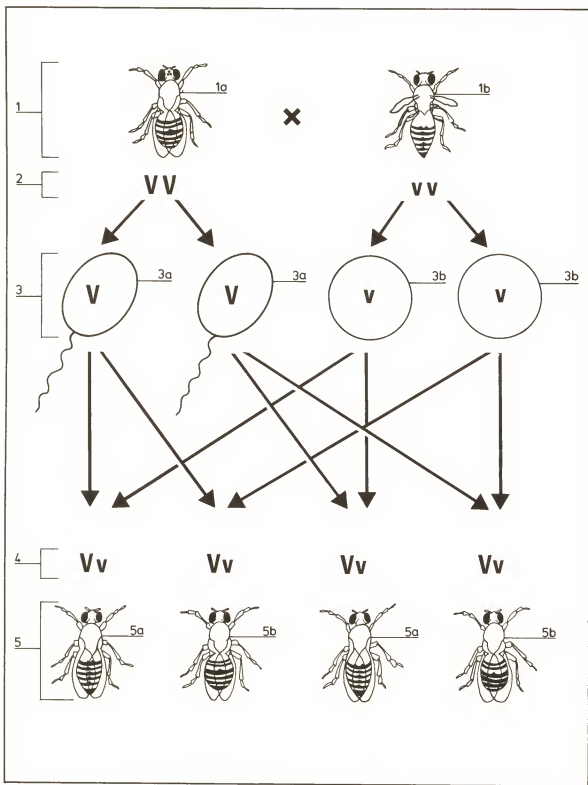


A ♂ *Drosophila*
B ♀ *Drosophila*
C ♂ chromosomes
D ♀ chromosomes

- 1 Rounded abdomen
2 Pointed abdomen with separate pigment bands
3 Sex comb

***Drosophila*: monohybrid cross 1**

02.043

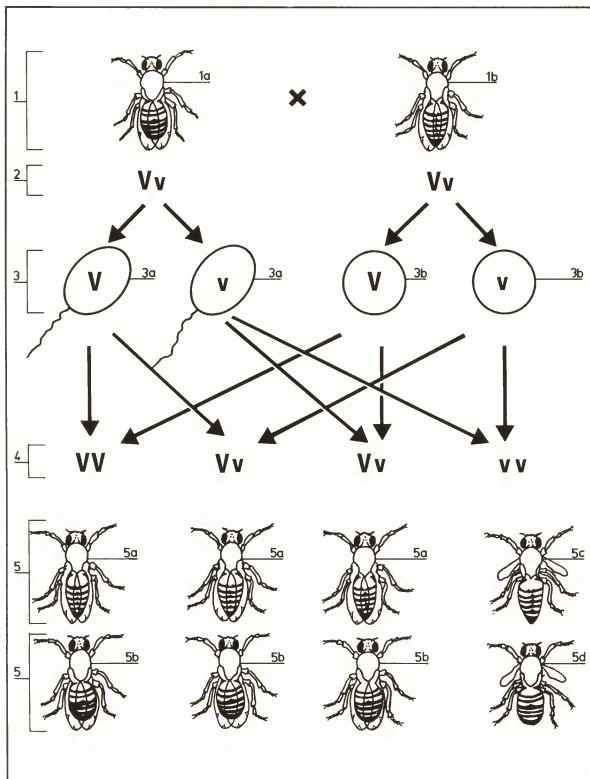


- 1 Parental phenotype
- 1a Normal-winged ♂
- 1b Vestigial-winged ♀
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 3a Sperm
- 3b Ovum
- 4 F_1 genotype
- 5 F_1 phenotype

- 5a Normal-winged ♀
- 5b Normal-winged ♂

***Drosophila*: monohybrid cross 2**

02.044



1 F₁ phenotype

1a Normal-winged ♂

1b Normal-winged ♀

2 F₁ genotype

3 Gametes produced by meiosis

3a Sperm

3b Ovum

4 F₂ genotype

5 F₂ phenotype

5a Normal-winged ♀

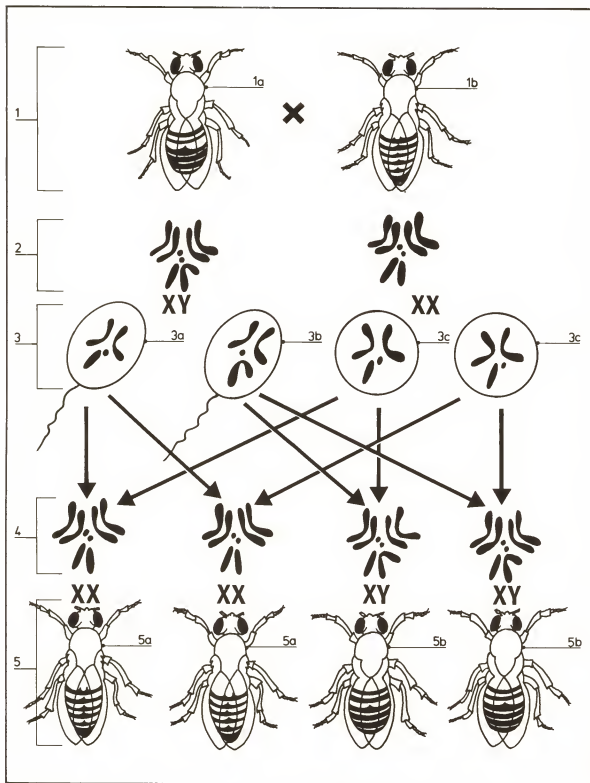
5b Normal-winged ♂

5c Vestigial-winged ♀

5d Vestigial-winged ♂

***Drosophila*: sex inheritance**

02.045



© DIAGRAM

1 Parental phenotype

1a ♂ *Drosophila*

1b ♀ *Drosophila*

2 Parental genotype

3 Gametes produced by meiosis

3a Sperm carrying X chromosome

3b Sperm carrying Y chromosome

3c Ovum

4 F₁ genotype

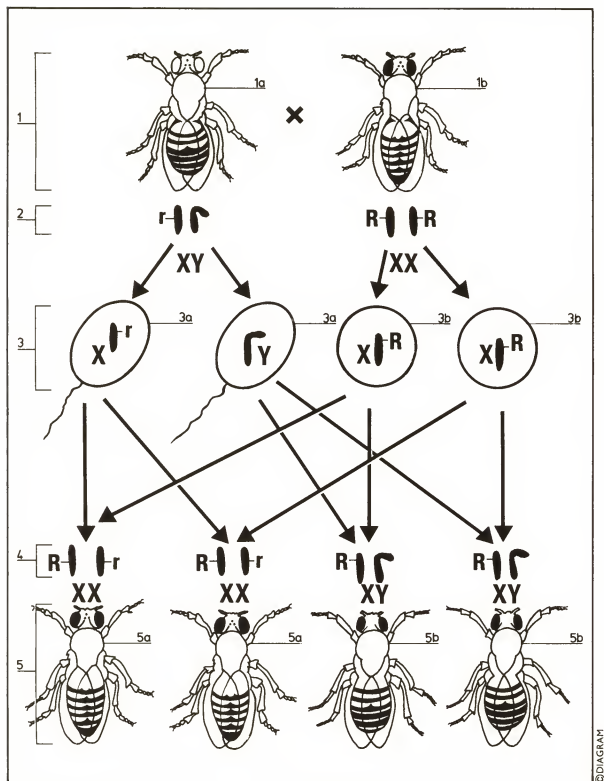
5 F₁ phenotype

5a ♀ *Drosophila*

5b ♂ *Drosophila*

***Drosophila*: sex linkage 1**

02.046

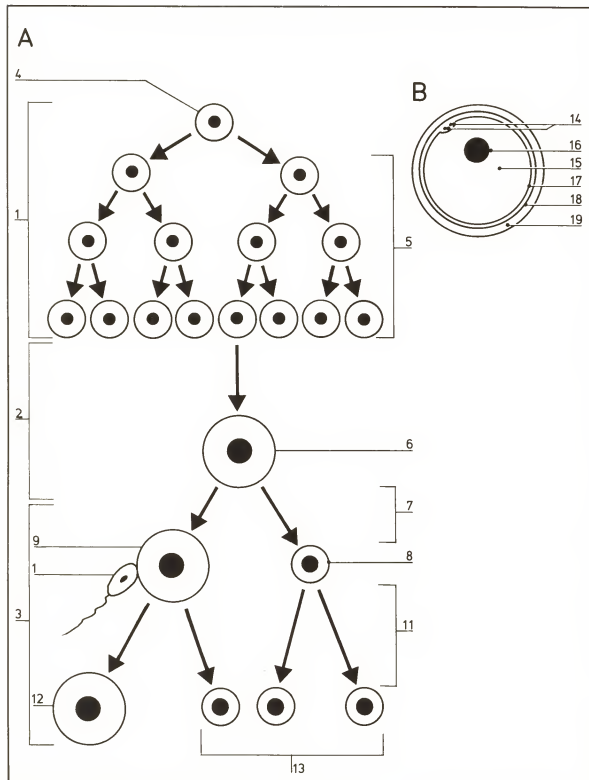


- 1 Parental phenotype
1a White-eyed ♂
1b Red-eyed ♀
2 Parental genotype
3 Gametes produced by meiosis
3a Sperm
3b Ovum
4 F₁ genotype
5 F₁ phenotype

- 5a Red-eyed ♀
5b Red-eyed ♂

Oogenesis 1

02.024



A Oogenesis - schematic
B Secondary oocyte prior to fertilization

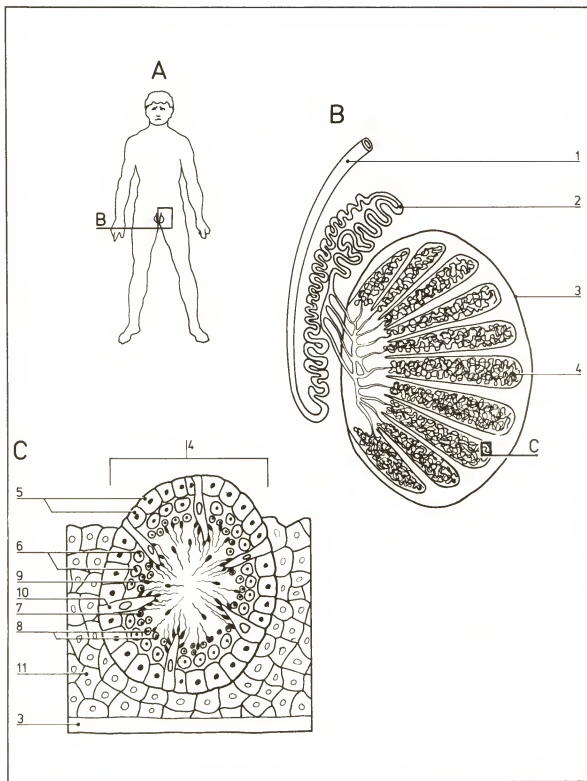
1 Phase of multiplication by mitosis
2 Phase of growth
3 Phase of maturation
4 Germ cell
5 Oogonia

6 Primary oocyte
7 Meiosis I
8 First polar body
9 Secondary oocyte
10 Spermatozoon
11 Meiosis II
12 Ovum
13 Second polar bodies
14 Polar bodies
15 Cytoplasm

16 Nucleus
17 Plasma membrane
18 Vitelline membrane
19 Zona pellucida

Spermatogenesis 2

02.023



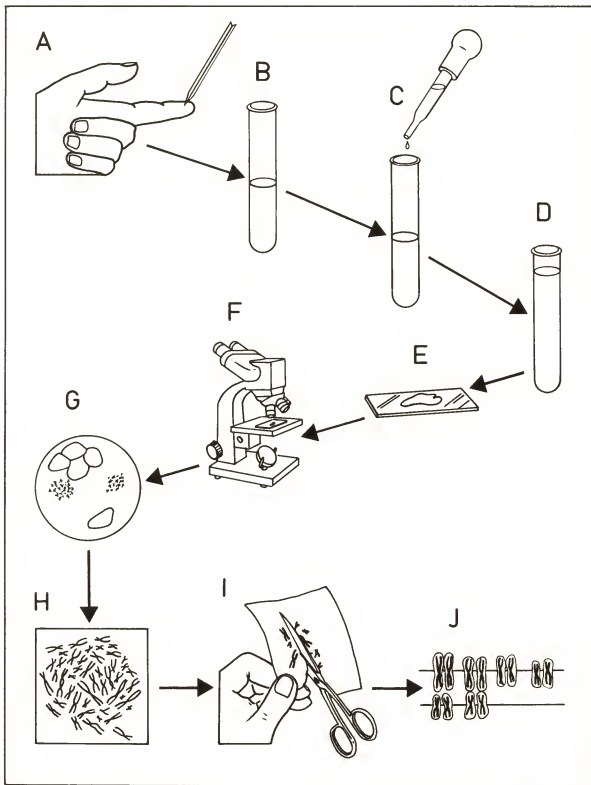
A Male human
B Testis – vertical section
C Seminiferous tubule –
transverse section

1 Vas deferens
2 Epididymis
3 Outer wall of testis
4 Seminiferous tubule –
cross section

5 Germ cells
6 Spermatogonia
7 Primary spermatocyte
8 Secondary
spermatocytes and
spermatids
9 Spermatozoon
10 Sertoli cell
11 Leydig cell

Karyotype preparation

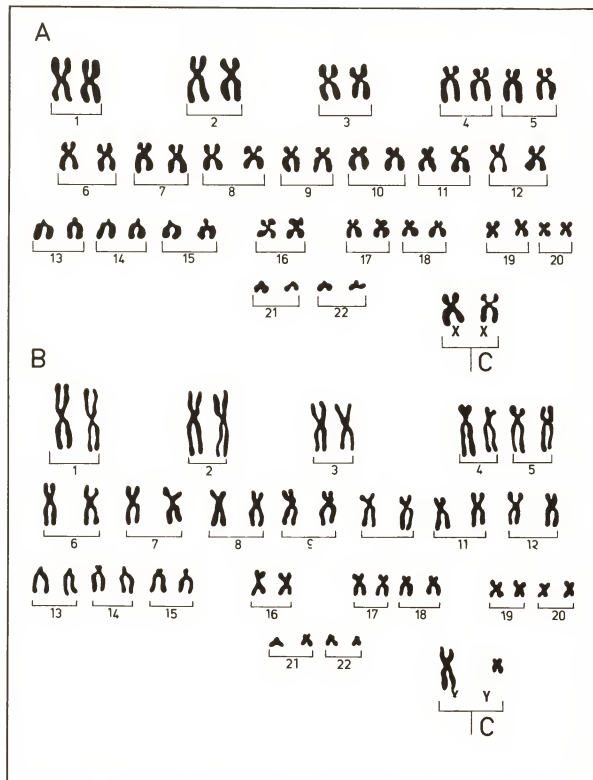
02.049



- A Blood sample removed from donor
B Sample suspended in saline; red cells settle out
C Colchicine added – stops cell division at metaphase
D Water added – cells swell and burst
E Cells spread onto slide
F–G Cells observed under microscope
H Chromosomes photographed
I Individual chromosomes cut out
J Chromosomes arranged in order of diminishing size

Human chromosomes

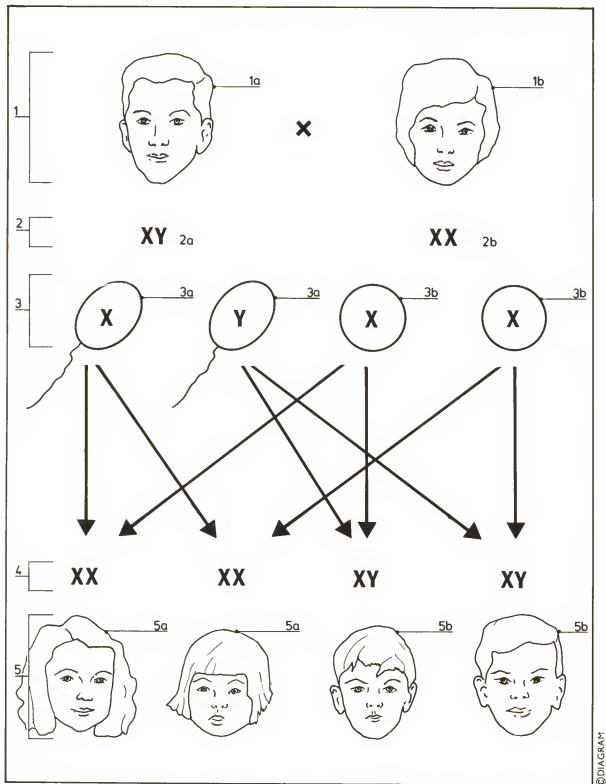
02.050



A ♀ karyotype
B ♂ karyotype
C Sex chromosomes

Human sex inheritance

02.051



©DIAGRAM

1 Parental phenotype

1a ♂

1b ♀

2 Parental genotype

2a X and Y sex chromosomes

2b X sex chromosomes

3 Gametes produced by meiosis

3a Sperm

3b Ovum

4 F₁ genotype

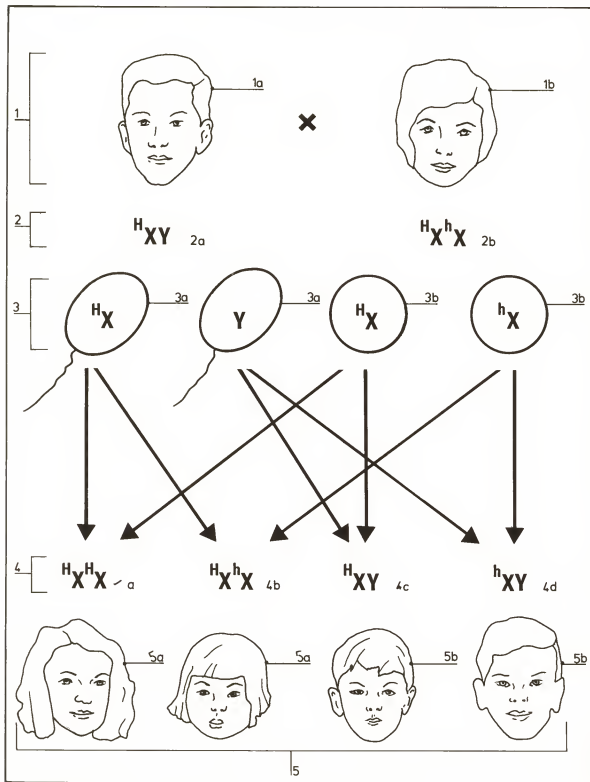
5 F₁ phenotype

5a ♀

5b ♂

Human sex linkage: hemophilia

02.052



© DIAGRAM

1 Parental phenotype

1a ♂

1b ♀

2 Parental genotype

2a Normal ♂

2b Carrier ♀

3 Gametes produced by meiosis

3a Sperm

3b Ovum

4 F₁ genotype

4a Normal ♀

4b Carrier ♀

4c Normal ♂

4d Hemophiliac ♂

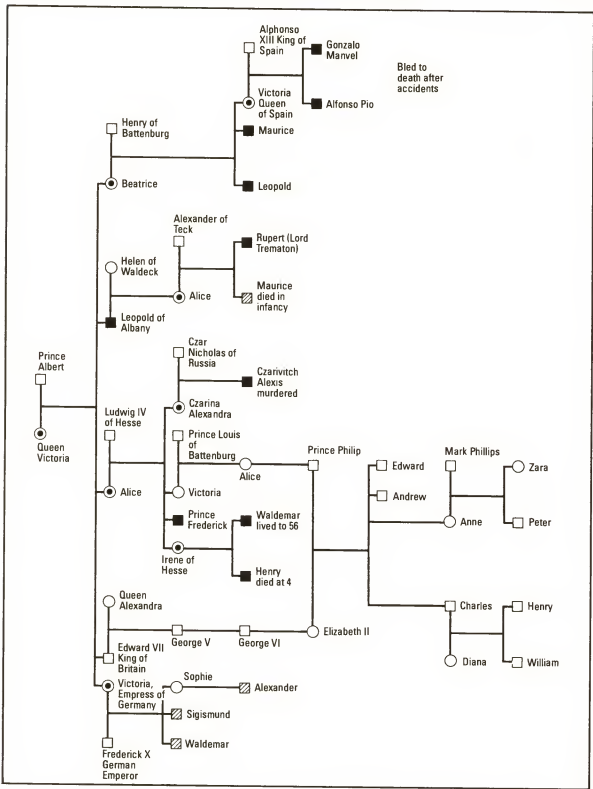
5 F₁ phenotype

5a ♀

5b ♂

Hemophilia inheritance: the royal families of Europe

02.053

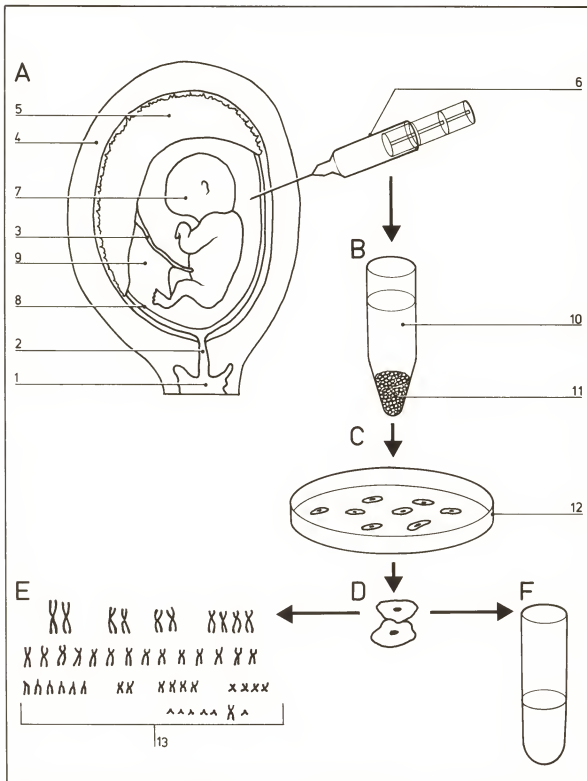


- Normal ♀
- Carrier ♀
- Normal ♂
- ▨ Possible ♂ hemophiliac
- ♂ hemophiliac

© DIAGRAM

Amniocentesis

02.054



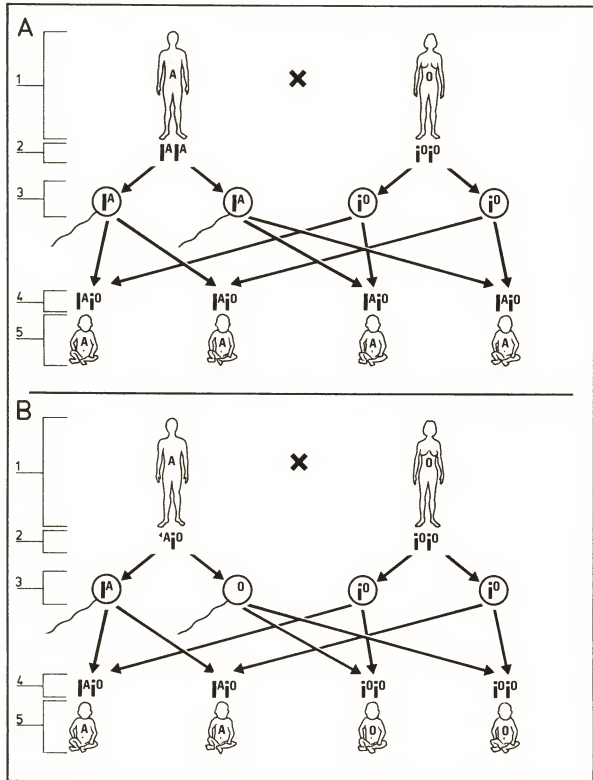
- A Sample of amniotic fluid, including cells
B Amniotic fluid centrifuged
C Cells grown in nutrient solution
D Cultured cells
E Chromosomal analysis
F Biochemical analysis

- 1 Vagina
2 Cervix
3 Umbilical cord

- 4 Uterine wall
5 Placenta
6 Syringe
7 Fetus
8 Amnion
9 Amniotic fluid
10 Supernatant
11 Cells
12 Culture dish
13 Down's syndrome karyotype

Multiple alleles: blood groups 1

02.055



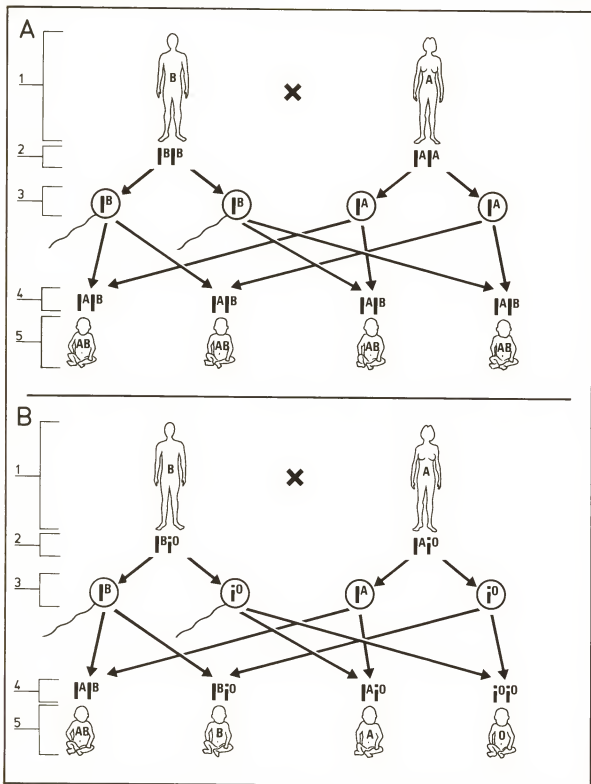
©DIAGRAM

A IAIA × iiO
B IAiO × iiO

- 1 Parental phenotype
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 4 F1 genotype
- 5 F1 phenotype

Multiple alleles: blood groups 2

02.056

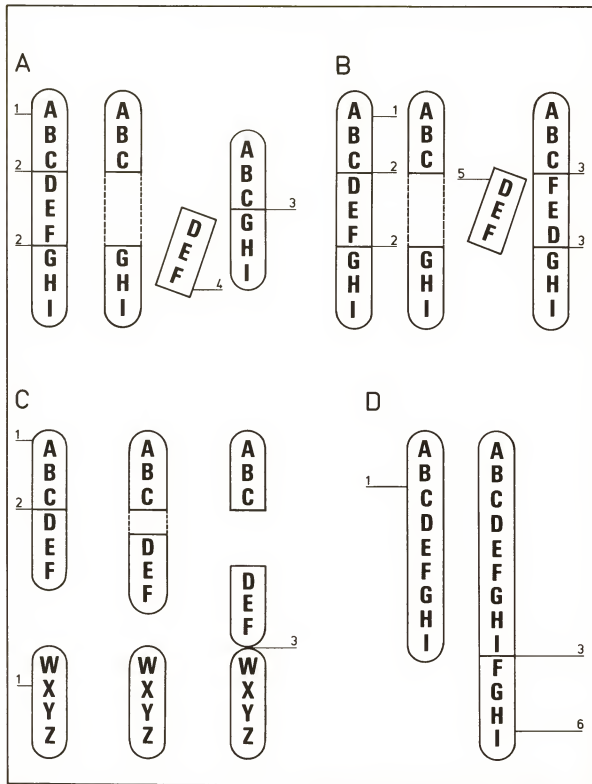


A $I^B I^B \times I^A I^A$
B $I^B i^O \times I^A i^O$

- 1 Parental phenotype
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 4 F₁ genotype
- 5 F₁ phenotype

Chromosome mutation 1

02.057



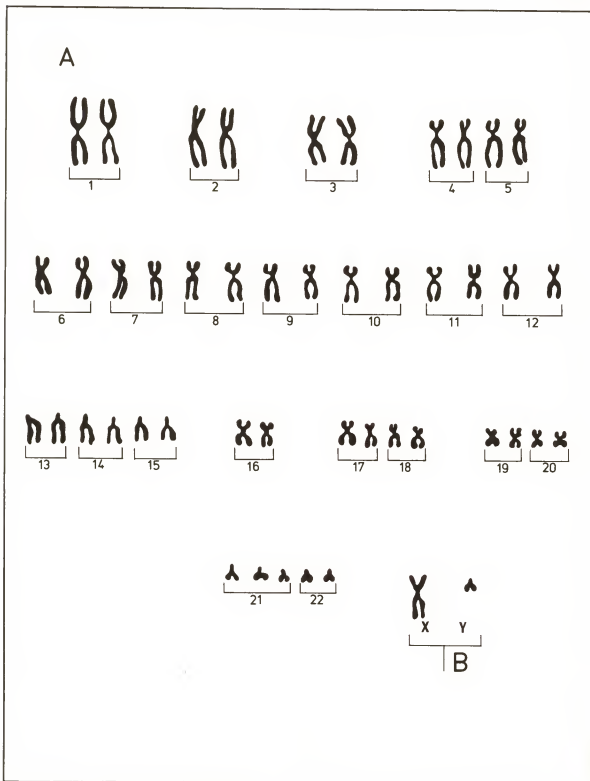
- A Deletion
B Inversion
C Translocation
D Duplication

- 5 Middle piece of chromosome rotates then rejoins
6 Extra piece of homologous chromosome added on

- 1 Normal chromosome
2 Position of break in chromosome
3 Position of join in chromosome
4 Middle piece of chromosome lost

Chromosome mutation 2

02.058

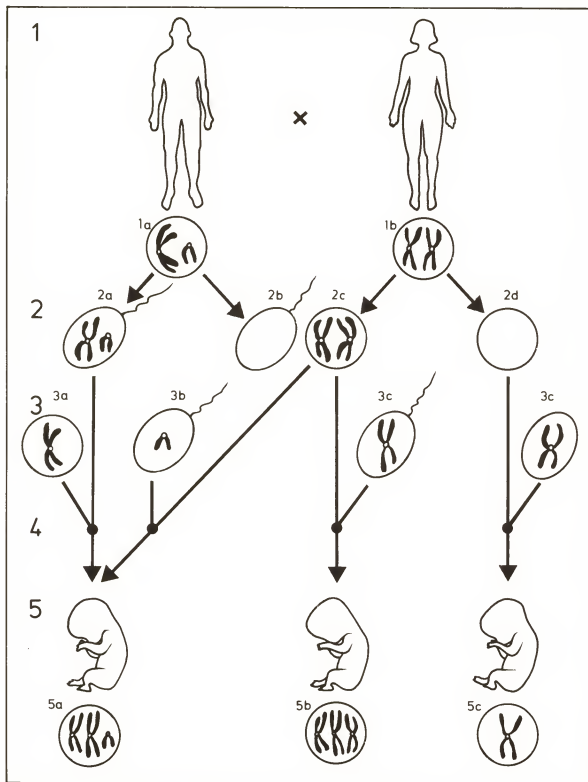


Non-disjunction – trisomy 21 (Down's syndrome)

- A ♂ karyotype
B Sex chromosomes

Chromosome mutation 3

02.059



Non-disjunction during gametogenesis

1 Parental phenotypes

1a ♂

1b ♀

2 Gametes produced by non-disjunction

2a Sperm with X and Y chromosomes

2b Sperm with no sex chromosomes

2c Ovum with two X chromosomes

2d Ovum with no sex chromosomes

3 Normal gametes

3a Ovum

3b Sperm with Y chromosome

3c Sperm with X chromosome

4 Fertilization

5 Possible genotypes of offspring

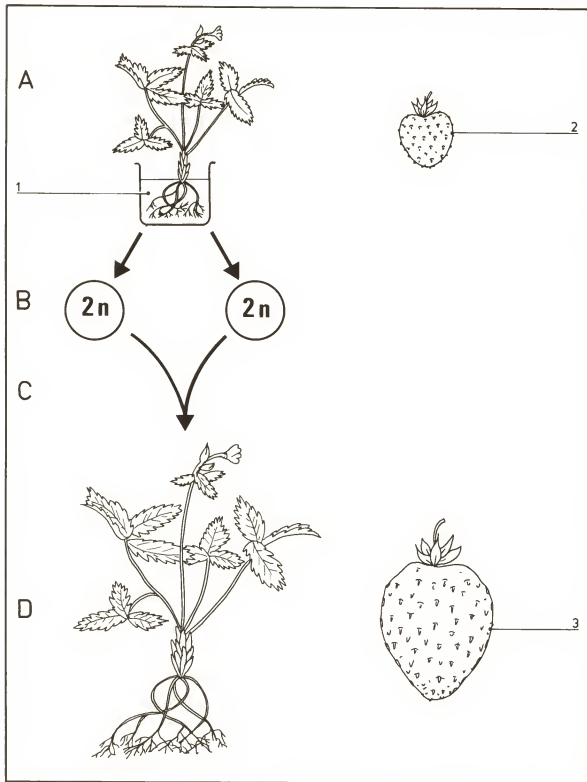
5a Klinefelter's syndrome

5b Triple X syndrome

5c Turner's syndrome

Chromosome mutation 4

02.060



Autopolyploidy – strawberry

A Diploid plant grown in colchicine solution

B Meiosis produces diploid gametes

C Fertilization

D Polyploid plant

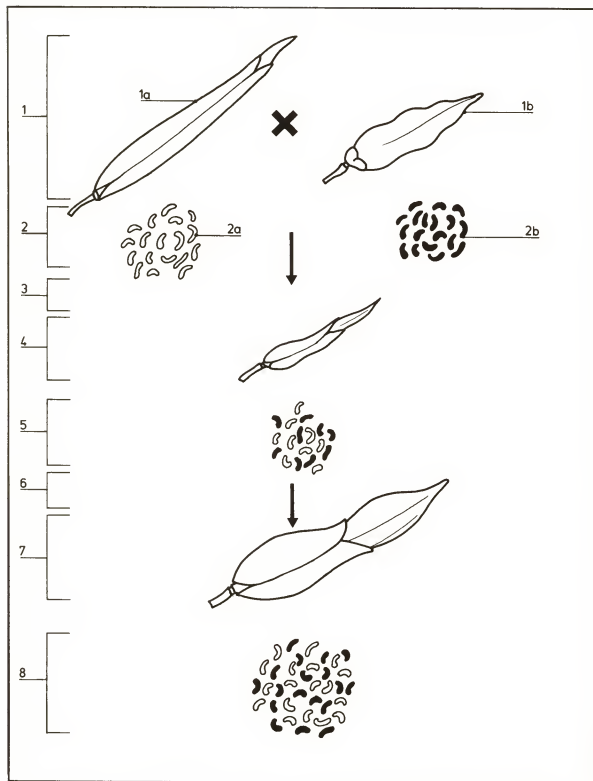
1 0.1% colchicine solution

2 Fruit of diploid plant

3 Fruit of polyploid plant

Chromosome mutation 5

02.061



1 Seed pods

1a Cabbage

1b Radish

2 Chromosomes

2a Cabbage genotype

2b Radish genotype

3 Meiosis and fertilization

4 F₁ sterile hybrid

5 Hybrid genotype

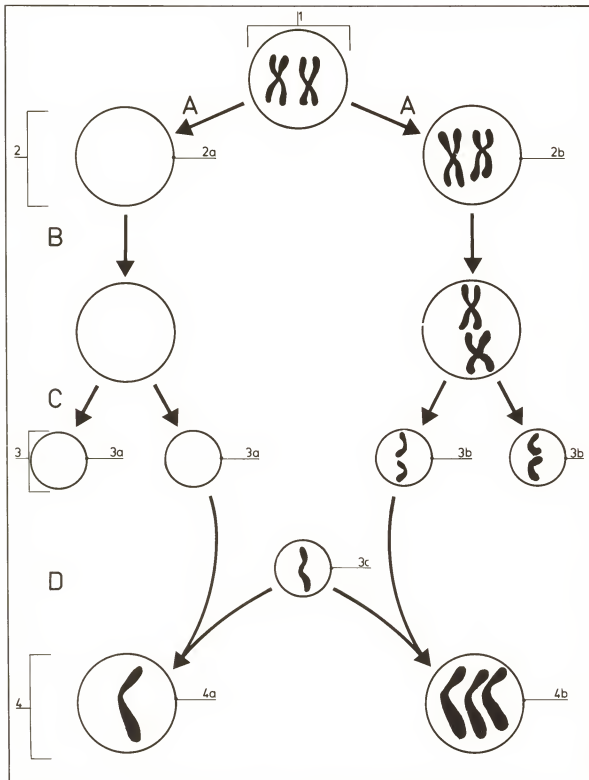
6 Reduction division fails to take place resulting in diploid gametes

7 Fertile tetraploid

8 Tetraploid genotype

Chromosome mutation 6

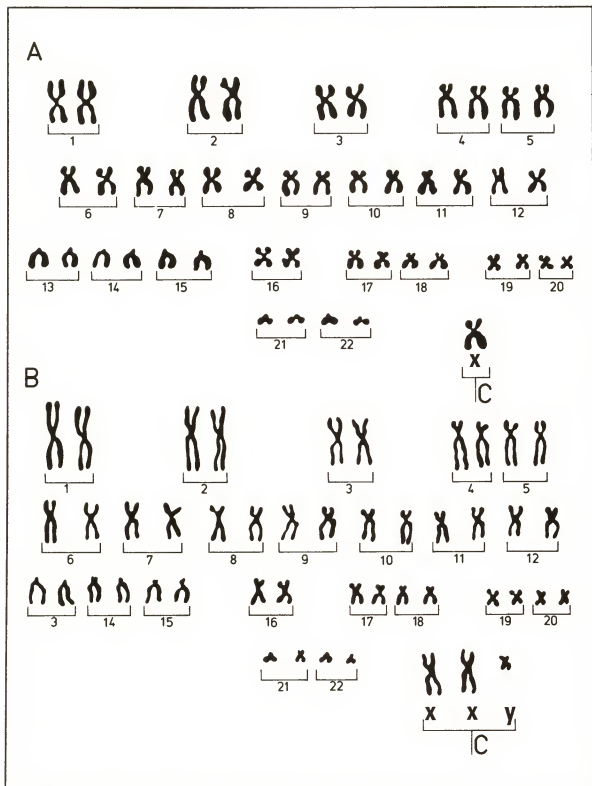
02.062



© DIAGRAM

Chromosome mutation 7

02.063

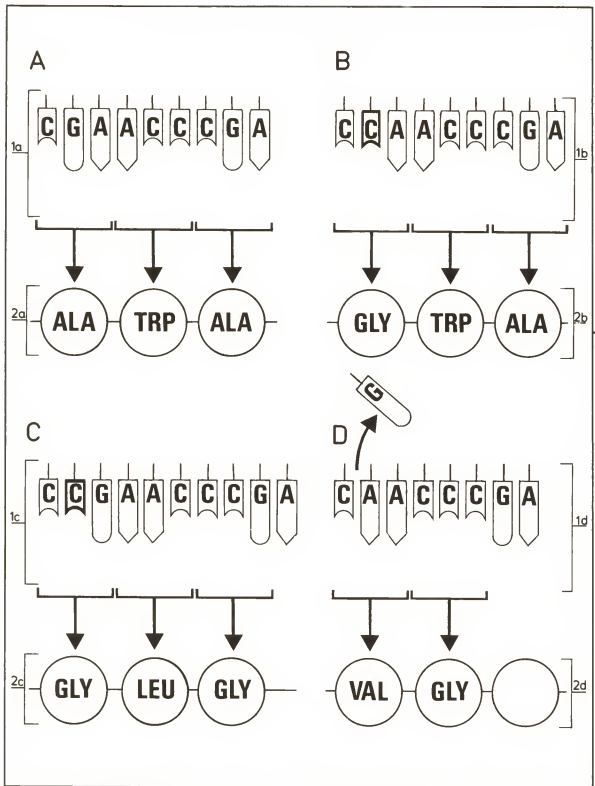


Non-disjunction of sex chromosomes

- A ♀ karyotype – Turner's syndrome
B ♂ karyotype – Klinefelter's syndrome
C Sex chromosomes

Gene mutation 1

02.064



A Normal DNA and polypeptide
B Substitution
C Insertion
D Deletion

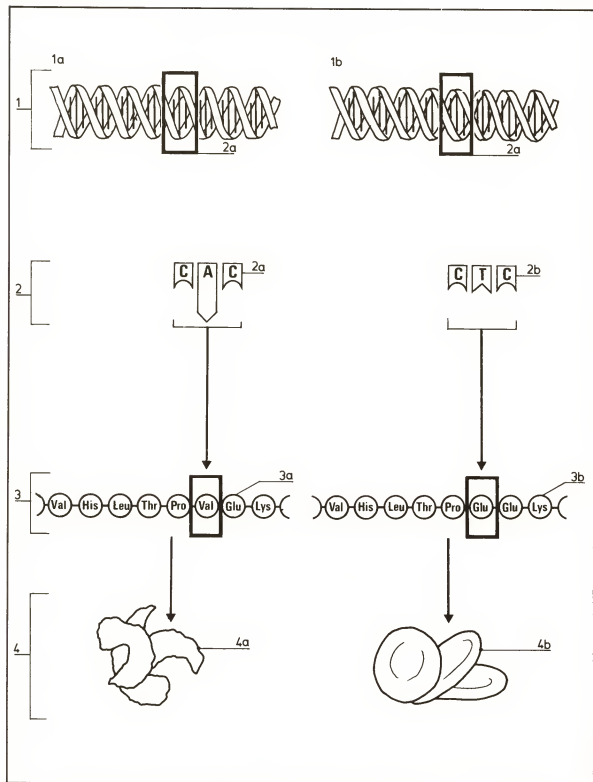
1 DNA
1a Normal DNA
1b DNA with base substituted
1c DNA with base inserted

1d DNA with base deleted
2 Polypeptide chains
2a Normal polypeptide chains
2b Mutant polypeptide chains
2c Mutant polypeptide chains
2d Mutant polypeptide chains

©DIAGRAM

Gene mutation 2

02.065



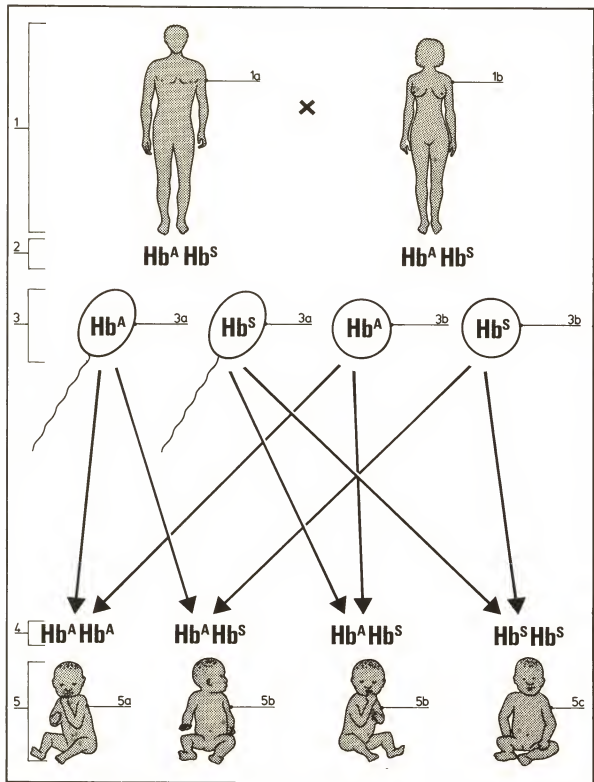
Substitution mutation producing abnormal hemoglobin

- 1 DNA
- 1a Mutant DNA
- 1b Normal DNA
- 2 DNA triplet coding for one amino acid in β hemoglobin
- 2a Triplet with base substitution
- 2b Normal triplet

- 3 Part of β hemoglobin
- 3a Abnormal chain with valine
- 3b Normal chain with glutamic acid
- 4 Red blood cells
- 4a Sick cells
- 4b Normal cells

Gene mutation 3

02.066



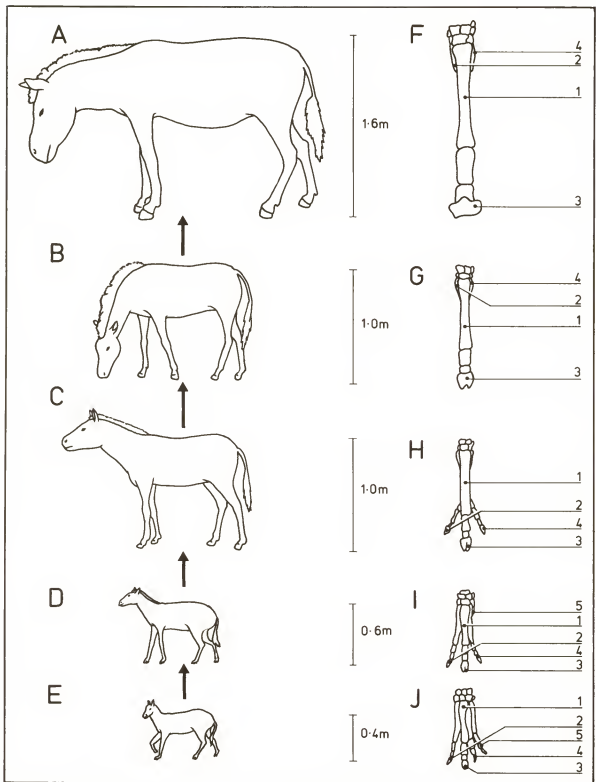
Genetics of sickle cell anemia

- 1 Parental phenotype
- 1a ♂ with sickle cell trait
- 1b ♀ with sickle cell trait
- 2 Parental genotype
- 3 Gametes produced by meiosis
- 3a Sperm
- 3b Ovum

- 4 F₁ genotype
- 5 F₁ phenotype
- 5a Child with normal hemoglobin
- 5b Child with sickle cell trait
- 5c Child with sickle cell anemia

Evidence for evolution 1

02.067



Fossil transition – horse

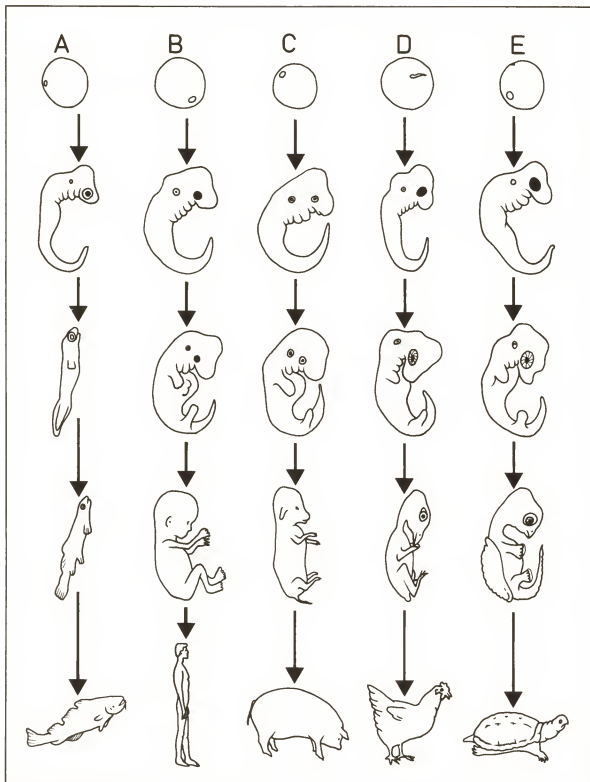
- A *Equus* (Pleistocene – recent)
- B *Pliohippus* (Pliocene)
- C *Merychippus* (Miocene)
- D *Mesohippus* (Oligocene)
- E *Hyracotherium* (Eocene)
- F Forefoot of *Equus*
- G Forefoot of *Pliohippus*

- H Forefoot of *Merychippus*
- I Forefoot of *Mesohippus*
- J Forefoot of *Hyracotherium*

- 1 Third metacarpal
- 2 Second digit
- 3 Third digit
- 4 Fourth digit
- 5 Fifth digit

Evidence for evolution 2

02.068



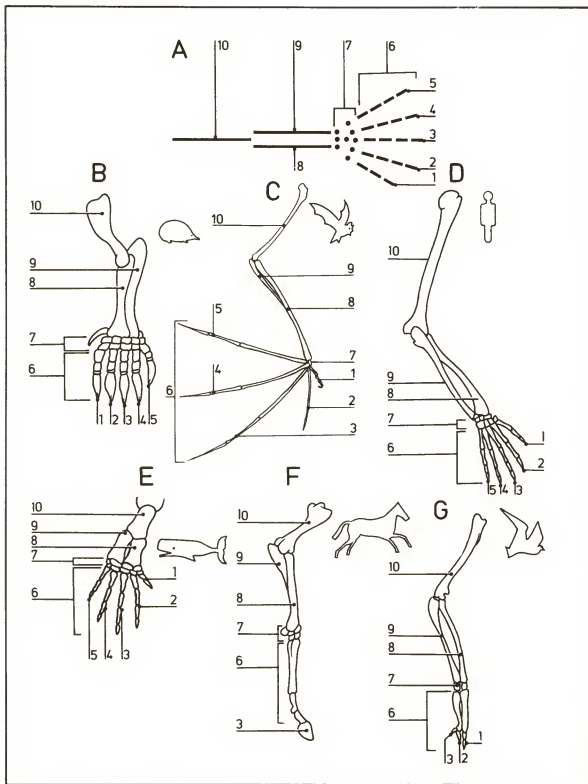
Comparison of vertebrate embryos

- A Fish
- B Human
- C Pig
- D Chicken
- E Turtle

© DIAGRAM

Evidence for evolution 3

02.069



Comparative anatomy – homologous structures (adaptive radiation)

A Basic pattern of forelimb bones (pentadactyl limb)

B–G Vertebrate forelimbs

B Mole (digging)

C Bat (flying)

D Human (grasping)

E Whale (swimming)

F Horse (running)

G Bird (flying)

1 First digit

2 Second digit

3 Third digit

4 Fourth digit

5 Fifth digit

6 Metacarpals and phalanges

7 Carpals

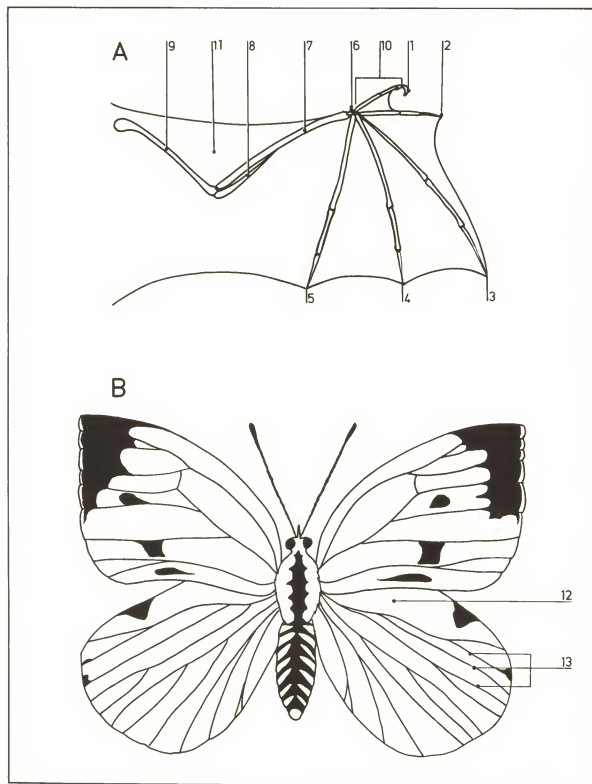
8 Radius

9 Ulna

10 Humerus

Evidence for evolution 4

02.070



Comparative anatomy – analogous structures
(convergent evolution)

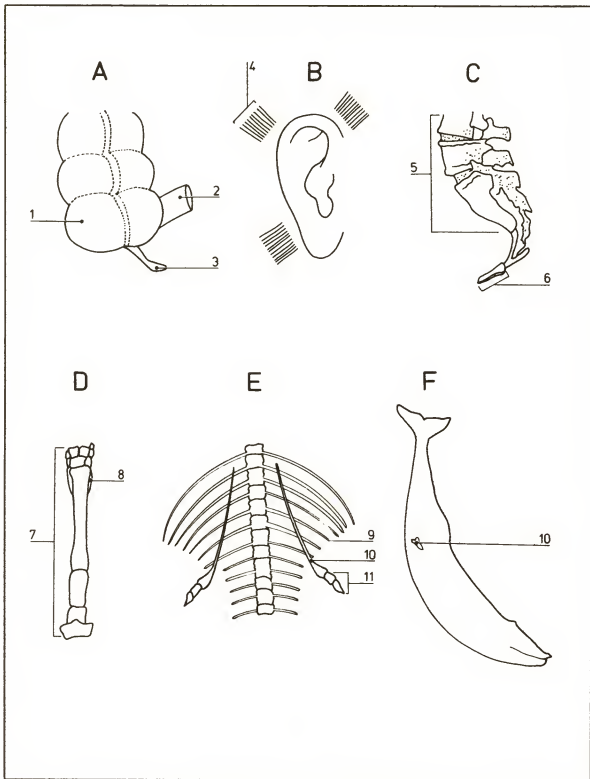
A Bat wing
B Butterfly wing

- 1 First digit
- 2 Second digit
- 3 Third digit
- 4 Fourth digit

- 5 Fifth digit
- 6 Carpals
- 7 Radius
- 8 Ulna
- 9 Humerus
- 10 Metacarpals and phalanges
- 11 Skin
- 12 Thin membrane
- 13 Network of veins support wing

Evidence for evolution 5

02.071



Vestigial organs

A-C in humans

D-E in other animals

A Appendix

B Ear muscles

C Coccyx

D Splint bone in

horse's leg

E Leg bones in snake

F Hipbone in whale

1 Large intestine

2 Small intestine

3 Appendix

4 Muscles

5 Sacrum

6 Coccyx

7 Forelimb

8 Splint bone

9 Rib

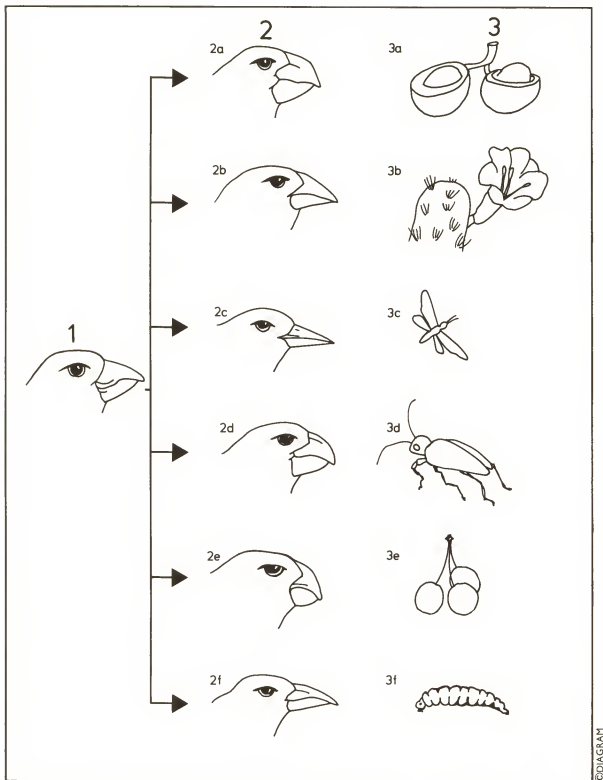
10 Hipbone

11 Leg bones

©DIAGRAM

Evidence for evolution 6

02.072



Adaptive radiation of Darwin's finches

















- 1 Typical mainland type (ancestral)
- 2 Galapagos finches
- 2a Large ground finch
- 2b Cactus ground finch
- 2c Warbler finch
- 2d Insectivorous tree finch
- 2e Vegetarian tree finch
- 2f Woodpecker (tool-using) finch

3 Food sources

- 3a Large seed
- 3b Cactus seeds and nectar
- 3c Flying insects
- 3d Large insects
- 3e Buds and fruit
- 3f Insect larvae

Evidence for evolution 7

02.073

A		0							
B		1	0						
C		9	8	0					
D		11	10	6	0				
E		14	15	18	17	0			
F		21	21	17	17	26	0		
G		31	30	26	27	31	32	0	
H		45	45	45	46	47	47	47	0
									
	A	B	C	D	E	F	G	H	

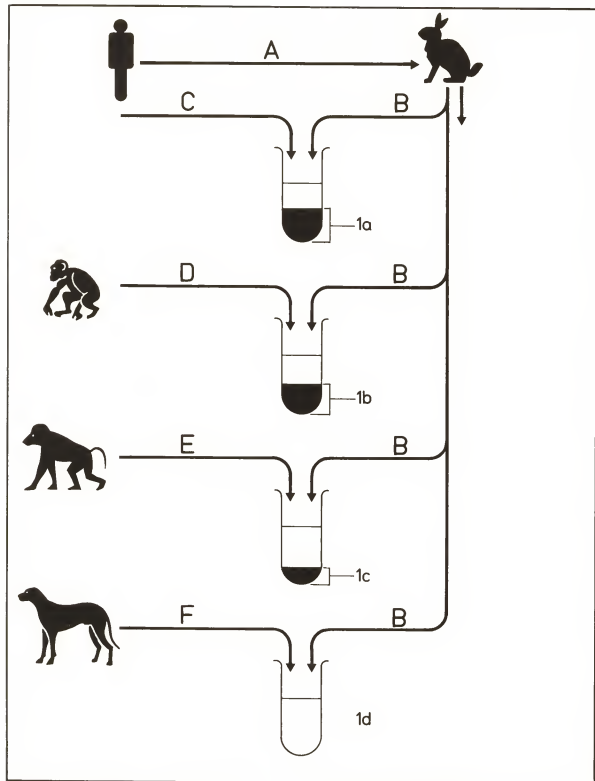
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Comparative biochemistry – cytochrome C analysis – the number of different amino acids in a range of species

- A Human
- B Rhesus monkey
- C Rabbit
- D Duck
- E Rattlesnake
- F Tuna
- G Moth
- H Yeast

Evidence for evolution 8

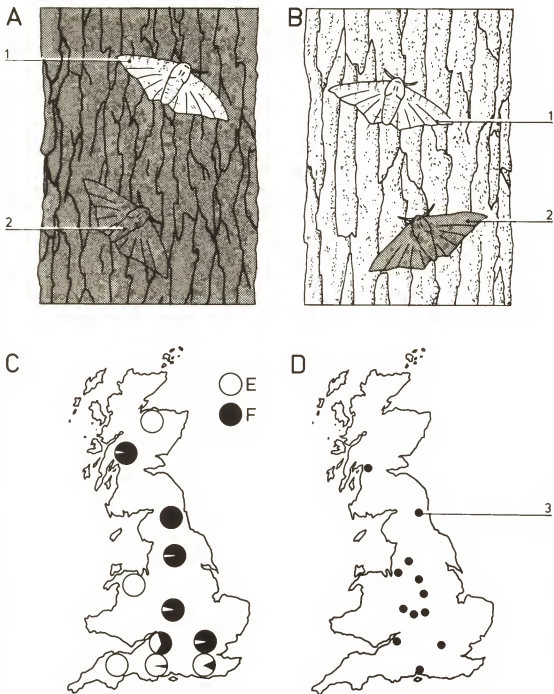
02.074



©DIAGRAM

Evidence for evolution 9

02.075



Industrial melanism

A Peppered moth (*Biston betularia*) on soot-blackened bark

B Peppered moth on lichen-covered bark

C Frequency of light and dark forms in different parts of the United Kingdom shown by pie charts

D Major industrial centers in the United Kingdom

E Frequency of light forms

F Frequency of dark forms

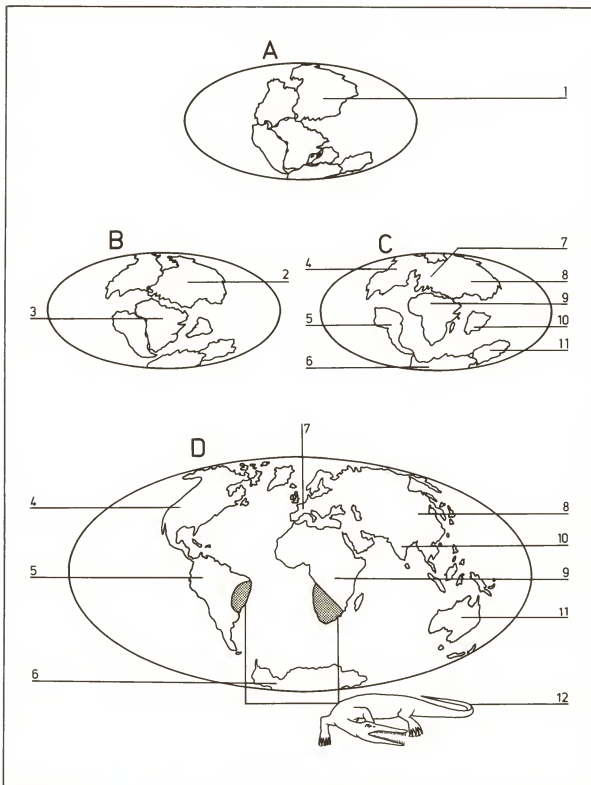
1 Light form

2 Dark (melanic) form

3 Major industrial center

Evidence for evolution 10

02.076

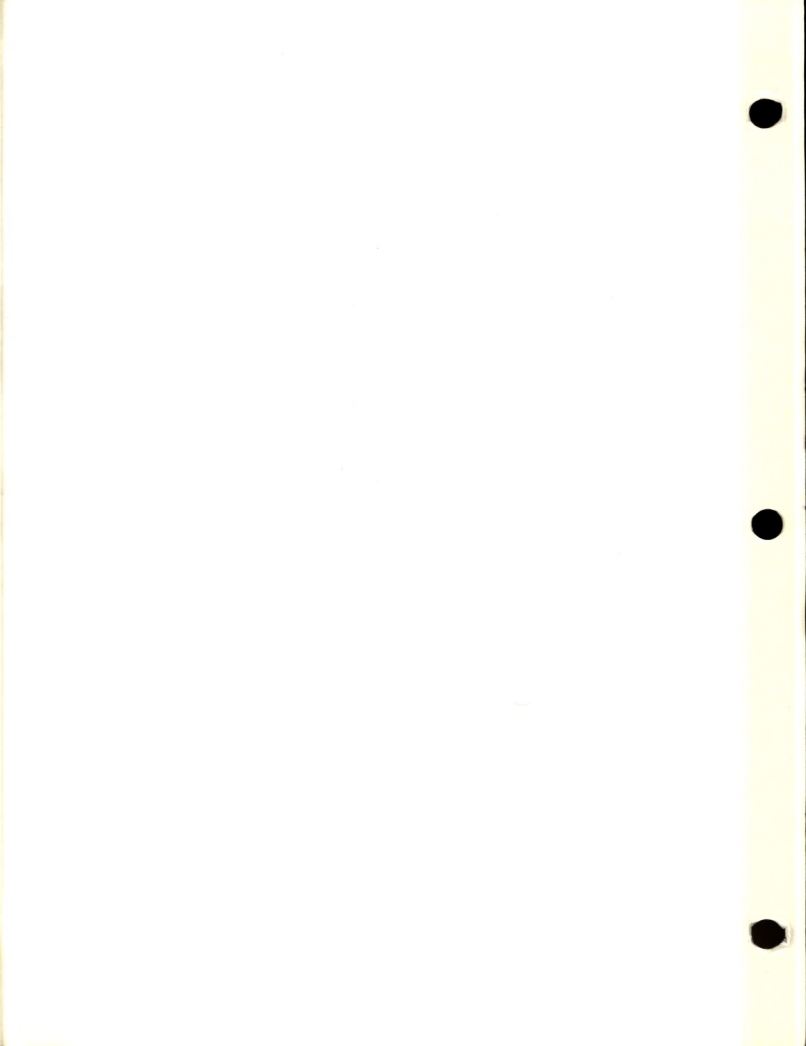


Continental drift

- A Supercontinent Pangaea (200 million years ago)
- B Break up of Pangaea into Laurasia and Gondwana (135 million years ago)
- C Separation of the land masses (65 million years ago)
- D Present day

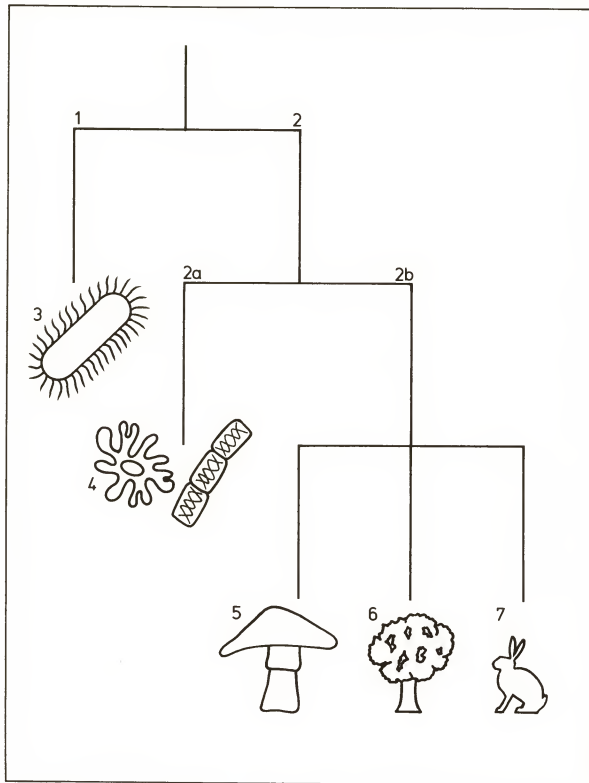
- 1 Pangaea
- 2 Laurasia
- 3 Gondwana

- 4 North America
- 5 South America
- 6 Antarctica
- 7 Europe
- 8 Asia
- 9 Africa
- 10 India
- 11 Australia
- 12 Fossil reptile *Mesosaurus* found only in South America and South West Africa



Classification of living organisms

03.001



©DIAGRAM

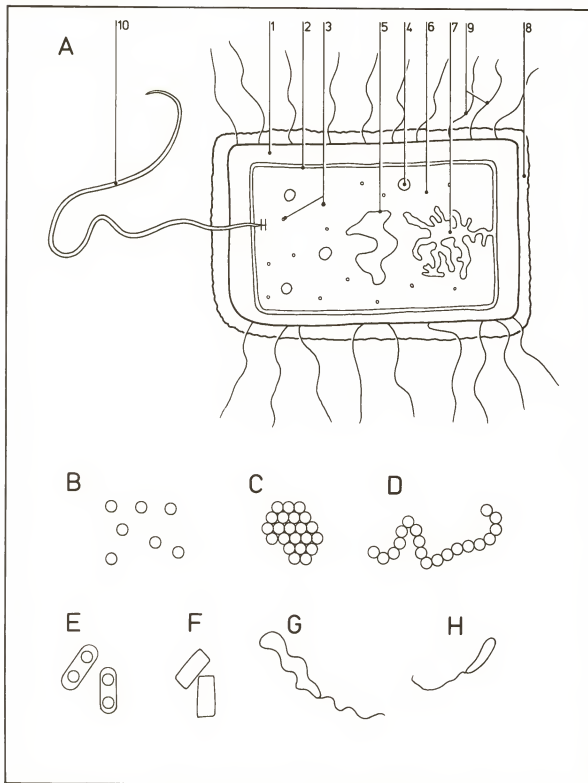
- | | |
|----------------------------|---------------------|
| 1 Prokaryotes | <i>Spirogyra</i> |
| 2 Eukaryotes | 5 Fungi |
| 2a Unicellular organisms | 6 Plantae (tree) |
| 2b Multicellular organisms | 7 Animalia (rabbit) |

Kingdoms
3 Monera (bacteria)
4 Protista (*Amoeba*,

Kingdom Monera

Bacterium

03.002



A Generalized rod-shaped bacterium (1.5µm)

B Cocci

C Staphylococci

D Streptococci

E Diplococci

F Bacilli

G Spirillum

H Vibrio

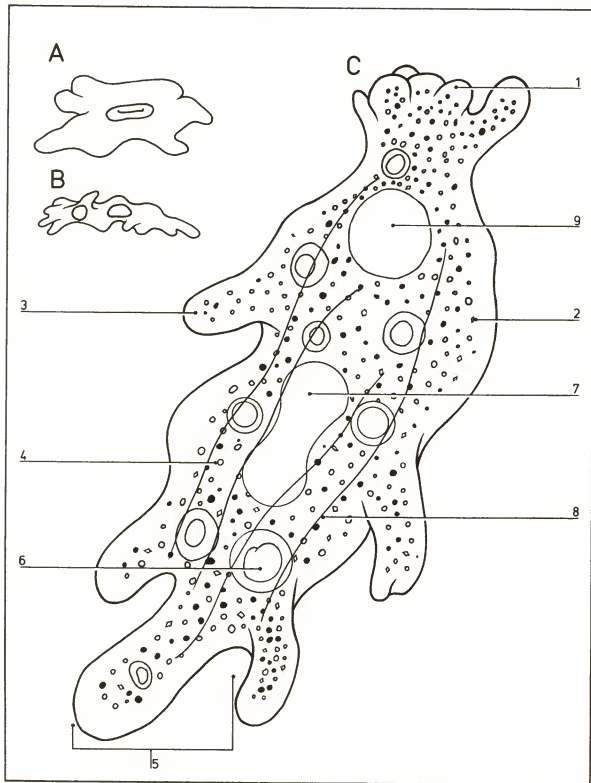
- 1 Cell wall
- 2 Cell membrane
- 3 Ribosomes
- 4 Food reserve
- 5 Genetic material (DNA)
- 6 Cytoplasm
- 7 Mesosome
- 8 Slime layer

- 9 Pili sometimes present
- 10 Flagellum sometimes present

Kingdom Protista

Ameba

03.003

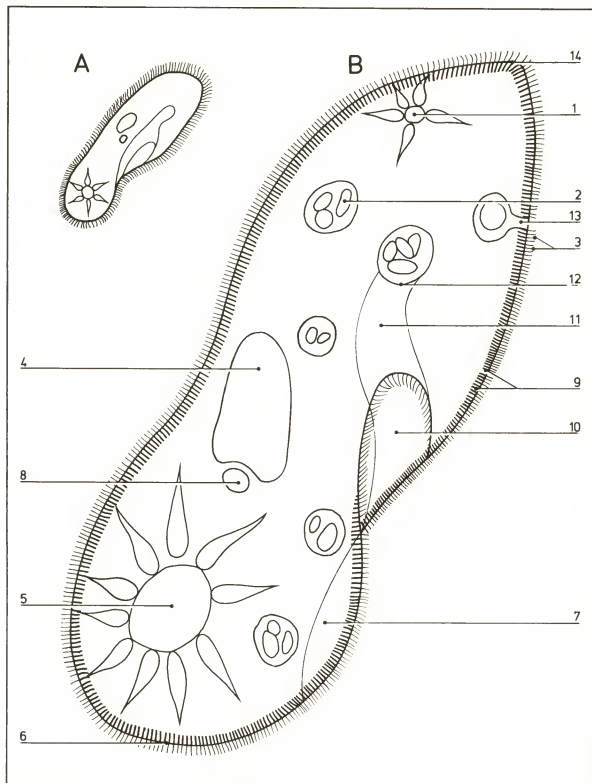


- | | |
|---------------------------|---|
| A External view | 4 Granular endoplasm |
| B External view (profile) | 5 Pseudopodium |
| C Internal structure | 6 Food vacuole containing ingested food |
| 1 Uroid | 7 Nucleus |
| 2 Crystal | 8 Ectoplasmic ridge |
| 3 Ectoplasm | 9 Contractile vacuule |

Kingdom Protista

Paramecium

03.004



A External view
B Internal structure

- 1 Posterior contractile vacuule
- 2 Food vacuole
- 3 Cilia
- 4 Large nucleus (macronucleus)

- 5 Anterior contractile vacuule
- 6 Anterior end
- 7 Oral groove
- 8 Small nucleus (micronucleus)
- 9 Trichocysts
- 10 Oral vestibule
- 11 Buccal cavity

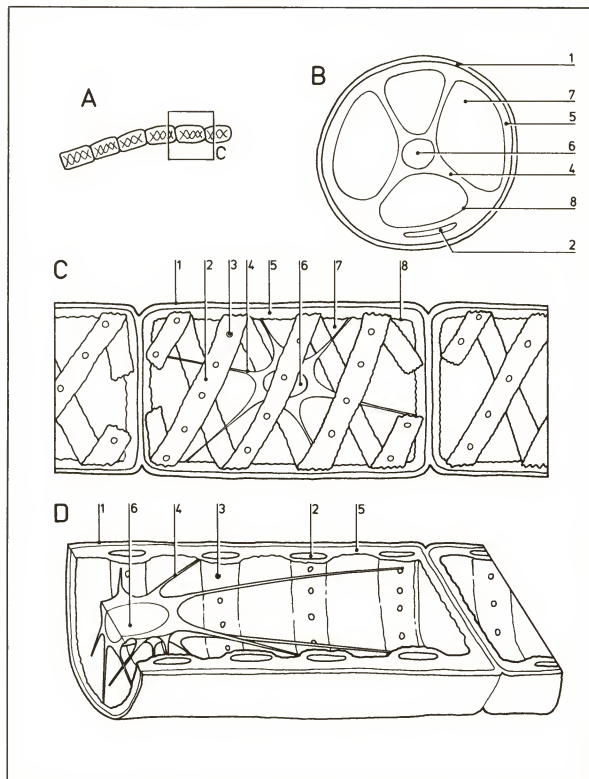
- 12 Cytostome
- 13 Cytoproct
- 14 Posterior end

©DIAGRAM

Kingdom Protista

Spirogyra

03.005



©DIAGRAM

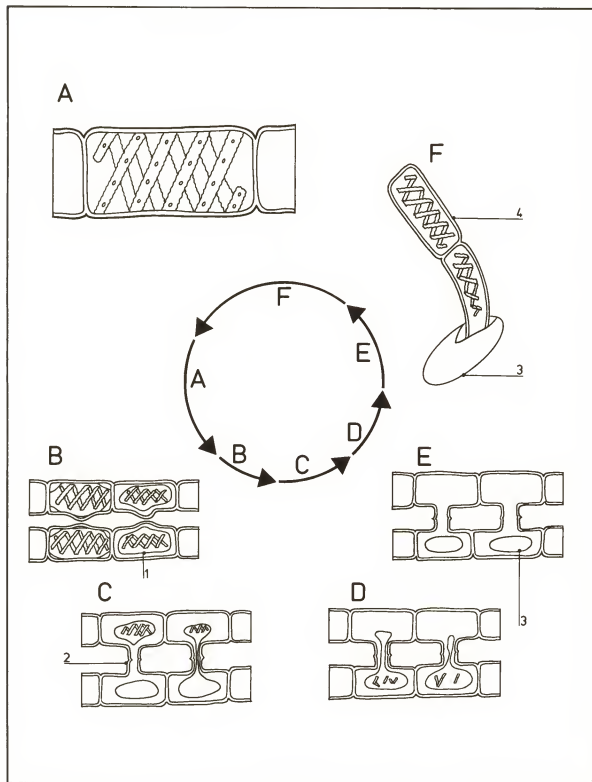
- | | |
|---|-----------------------------|
| A Filament | 4 Cytoplasmic strand |
| B Transverse section | 5 Cytoplasmic lining |
| C Single cell | 6 Nucleus |
| D Single cell – longitudinal section | 7 Vacuole |
| | 8 Tonoplast |

- 1 Cell wall
2 Chloroplast
3 Pyrenoid

Kingdom Protista

***Spirogyra*: sexual reproduction**

03.006



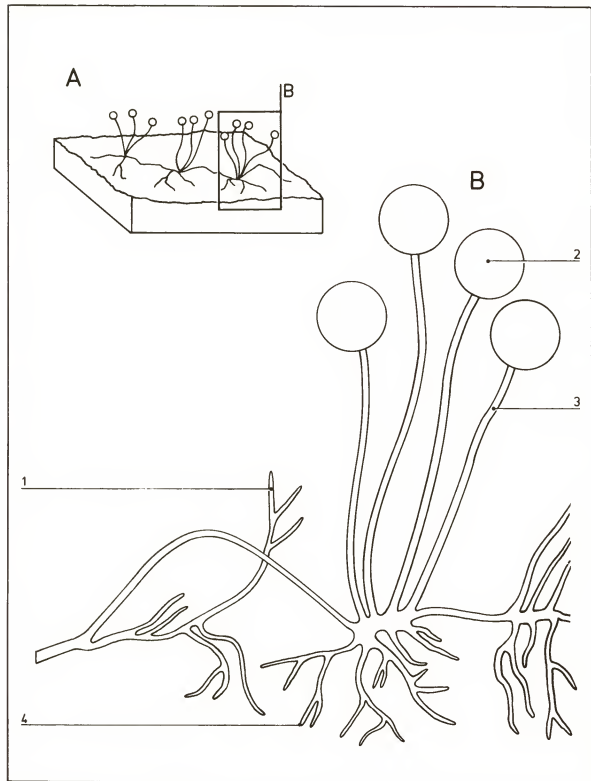
- A Mature filament cell
B Adjacent filaments – cells develop protuberances
C Cell contents round off
D Conjugation
E Zygospore formation
F Zygospore germinates

- 1 Cell membrane
2 Conjugation tube
3 Zygospore
4 New filament

Kingdom Fungi

Rhizopus

03.007



- A Mycelium on stale bread
B Mycelium (network of hyphae)

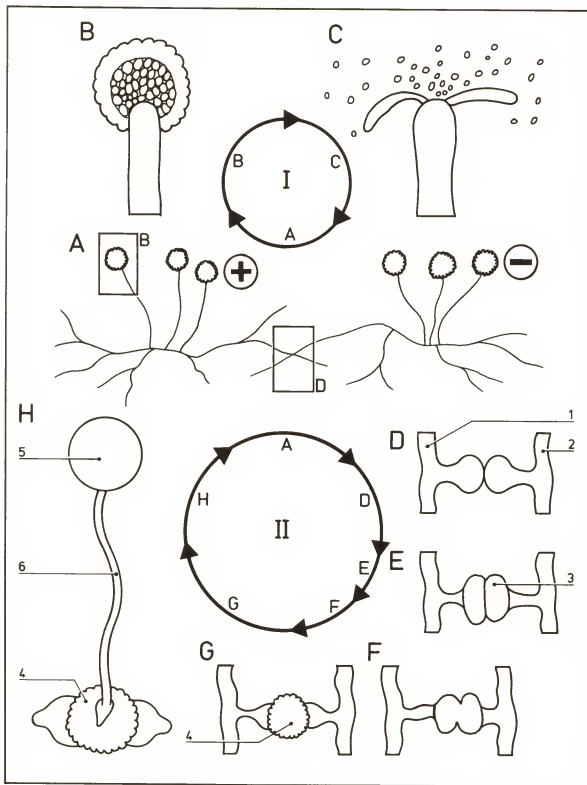
- 1 Hypha
2 Sporangium
3 Sporangiophore (aerial hypha)
4 Hyphae growing in food

©DIAGRAM

Kingdom Fungi

***Rhizopus*: reproduction**

03.008

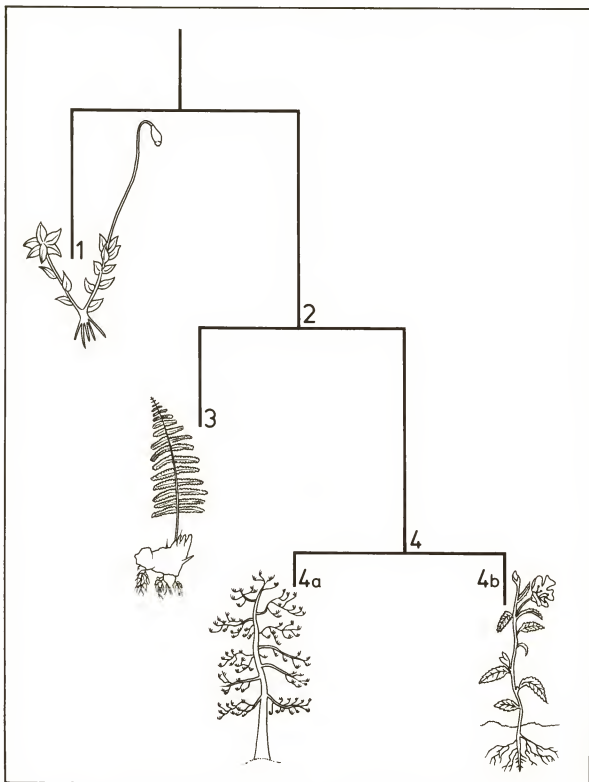


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Kingdom Plantae

Classification

03.009



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Phyla

- 1 Bryophyta
- 2 Tracheophyta

Subphyla

- 3 Pteridophyta
- 4 Spermatophyta

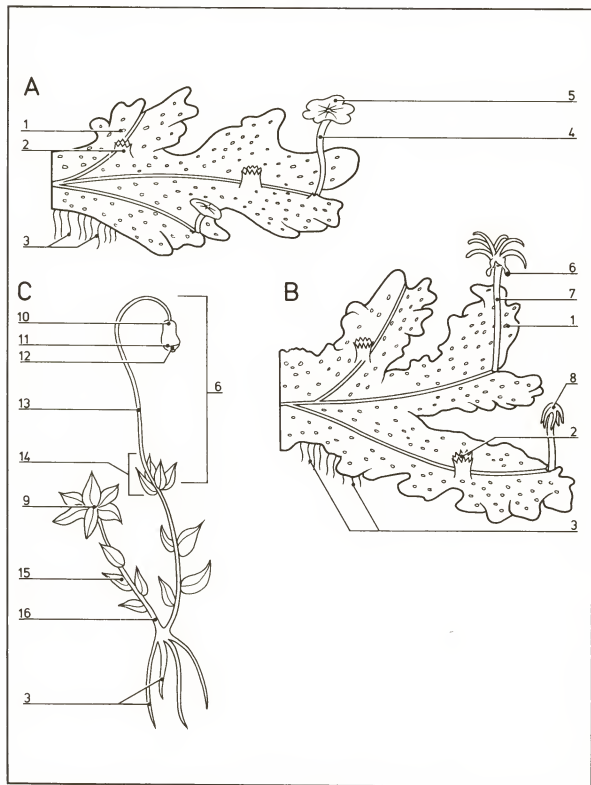
Classes

- 4a Gymnospermae
- 4b Angiospermae

Kingdom Plantae

Bryophyta

03.010



A Liverwort ♂ plant
B Liverwort ♀ plant
C Moss

1 Thallus
2 Gemma cup
3 Rhizoids
4 Antheridiophore
5 Receptacle carrying

antheridia
6 Sporophyte
7 Archegoniophore
8 Receptacle carrying archegonia
9 Antheridia
10 Capsule
11 Annulus
12 Operculum

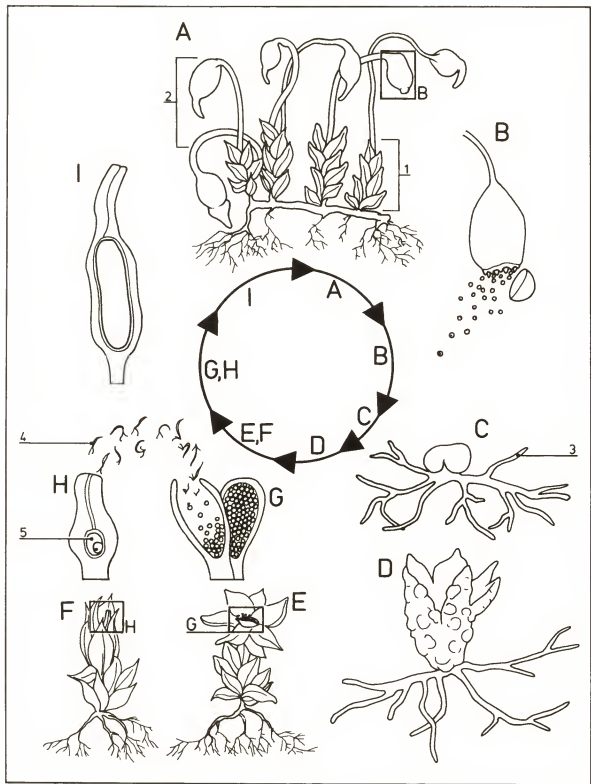
13 Seta
14 'Leaves' surrounding archegonia
15 'Leaf'
16 'Stem'

© DIAGRAM

Kingdom Plantae

Bryophyta: life cycle

03.011



© DIAGRAM

Moss

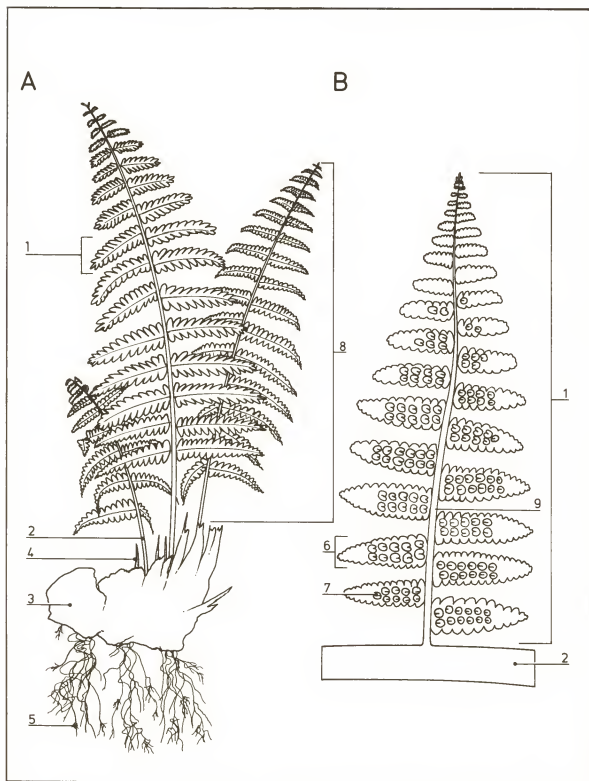
- A Mature sporophytes
- B Spores released from capsule
- C Spore germinates
- D Developing gametophyte
- E ♂ gametophyte
- F ♀ gametophyte
- G Antheridium releasing 'sperms' (antherozoids) which swim to archegonium

- H Archegonium containing 'eggs' (oospheres)
- I Developing sporophyte in archegonium
- 1 Gametophyte
- 2 Sporophyte
- 3 Protonema
- 4 'Sperm' (antherozoids)
- 5 'Egg' (oosphere)

Kingdom Plantae

Pteridophyta 1

03.012



Fern

A Sporophyte – external
view
B Pinna – lower surface

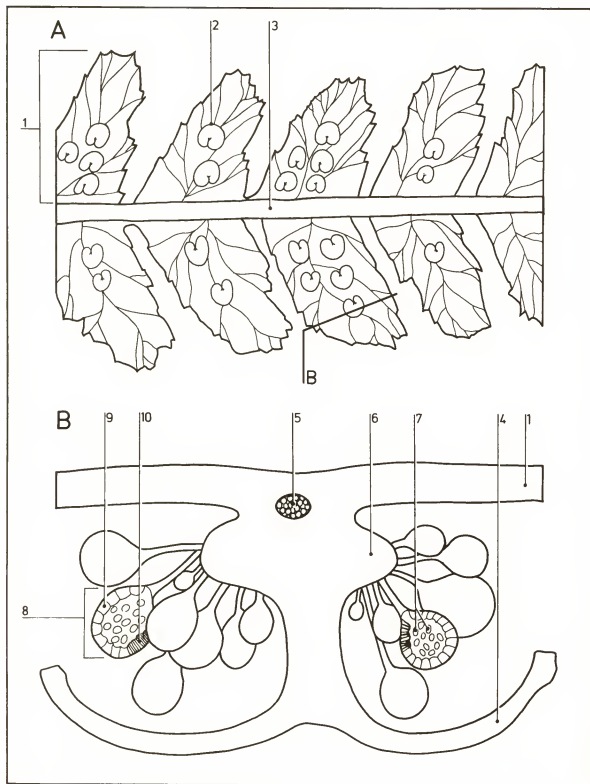
year's fronds
5 Roots (adventitious)
6 Pinnule
7 Sorus
8 Frond (leaf)
9 Midrib of pinna

1 Pinna (leaflet)
2 Rachis (stem)
3 Rhizome
4 Rases of previous

Kingdom Plantae

Pteridophyta 2

03.013



Fern

A Pinna – detail of lower surface

B Sorus – vertical section

1 Pinnule
2 Sorus
3 Rachis

4 Indusium of sorus

5 Vascular tissue

6 Placenta

7 Spores

8 Sporangium

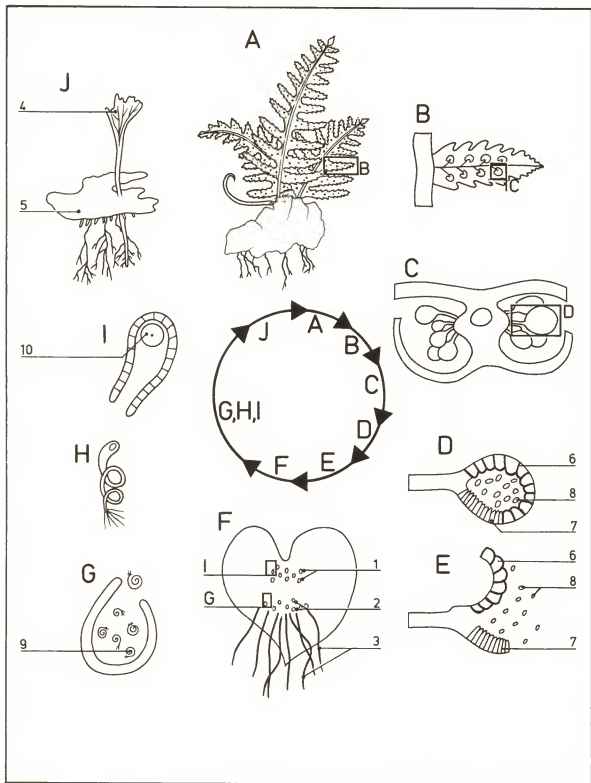
9 Annulus

10 Stomium

Kingdom Plantae

Pteridophyta: life cycle

03.014



© DIAGRAM

Fern

- A Mature sporophyte (diploid)
B Pinnule with sori
C Sorus – vertical section
D Spores produced in sporangium
E Spore dispersal

- F Gametophyte (haploid) – ventral surface
G Antheridium
H 'Sperm' (antherozoid) moving to archegonium
I Archegonium with 'egg' (oosphere)

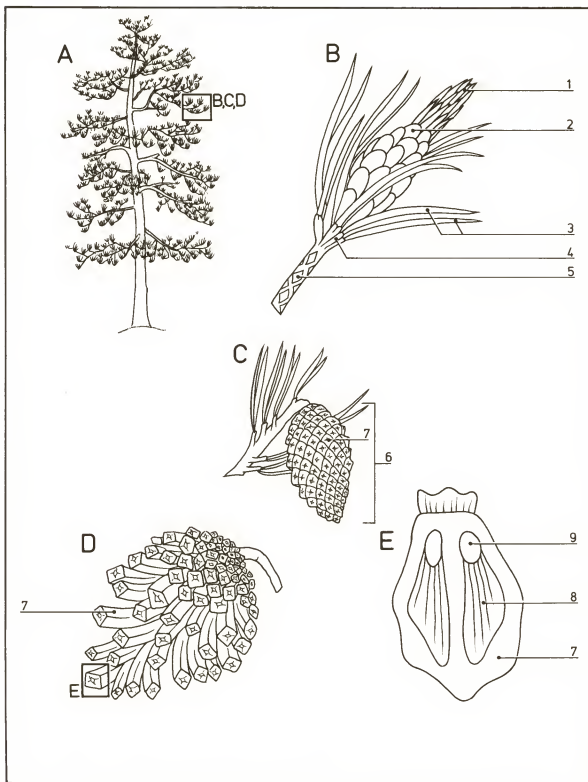
- J Sporophyte develops from fertilized 'egg' (oospore), absorbing food from gametophyte
1 Archegonia
2 Antheridia
3 Rhizoids

- 4 Sporophyte
5 Gametophyte (prothallus)
6 Annulus
7 Stomium
8 Spores
9 'Sperm' (antherozoid)
10 'Egg' (oosphere)

Kingdom Plantae

Gymnospermae

03.015



©DIAGRAM

A Pine tree
B ♂ cones
C ♀ cone before
fertilization
D ♀ cone after
fertilization
E Ovuliferous scale—
upper surface

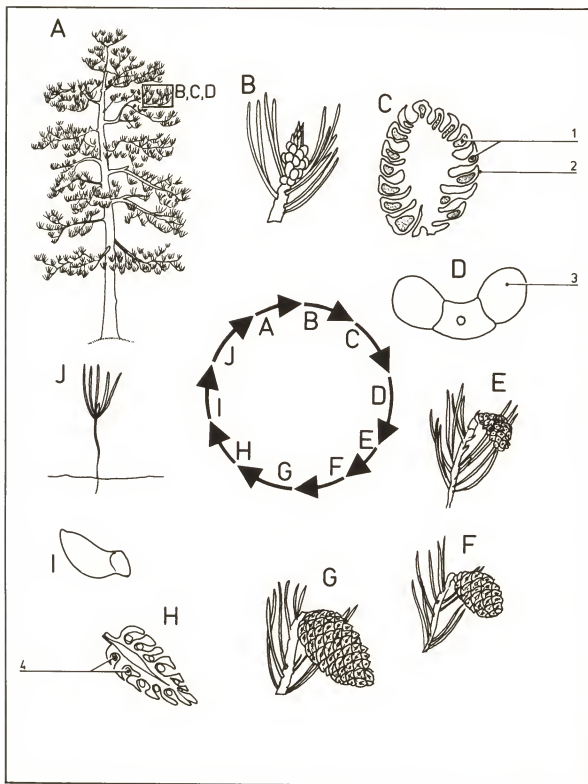
1 Shoot apex
(apical bud)
2 ♂ cone
3 Pair of leaves
(needles)
4 Dwarf shoot
5 Scar
6 ♀ cone
7 Ovuliferous scale

8 Wing of seed
9 Mature seed

Kingdom Plantae

Gymnospermae: life cycle

03.016



© DIAGRAM

A Pine tree

B ♂ cones

C ♂ cone – vertical section

D Pollen grain released into the air

E Pollen grain pollinates first year ♀ cone

F Second year ♀ cone (fertilization stage)

G Third year ♀ cone (mature)

H Ripe ♀ cone – vertical section

I Seed released into the air

J Seed germinates to produce seedling

1 Microsporangium containing pollen grains

2 Microspore

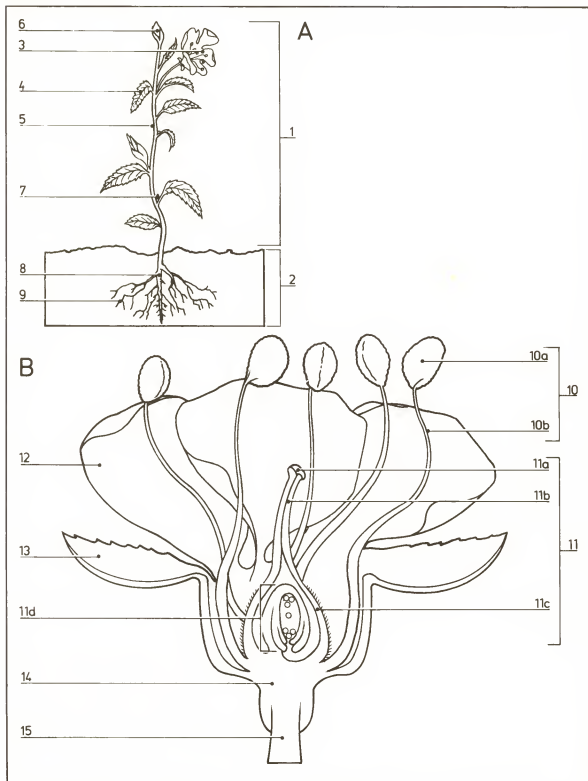
3 Air sac

4 Seeds

Kingdom Plantae

Angiospermae

03.017



A Typical angiosperm plant body

B Generalized flower – vertical section

- 1 Shoot
- 2 Root
- 3 Flower
- 4 Leaf

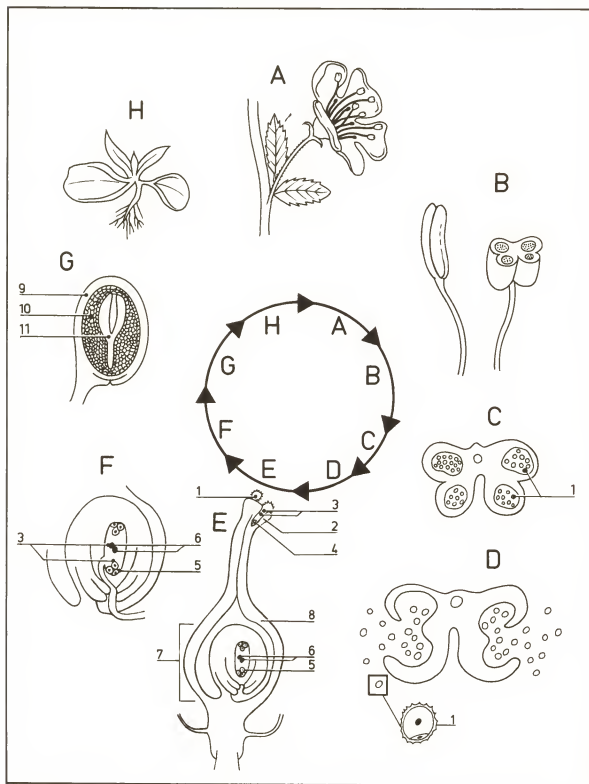
- 5 Stem
- 6 Terminal bud
- 7 Axillary bud
- 8 Tap root
- 9 Lateral root
- 10 Stamen
- 10a Anther
- 10b Filament
- 11 Pistil

- 11a Stigma
- 11b Style
- 11c Ovary
- 11d Ovule
- 12 Petal
- 13 Sepal
- 14 Receptacle
- 15 Pedicel

Kingdom Plantae

Angiospermae: life cycle

03.018



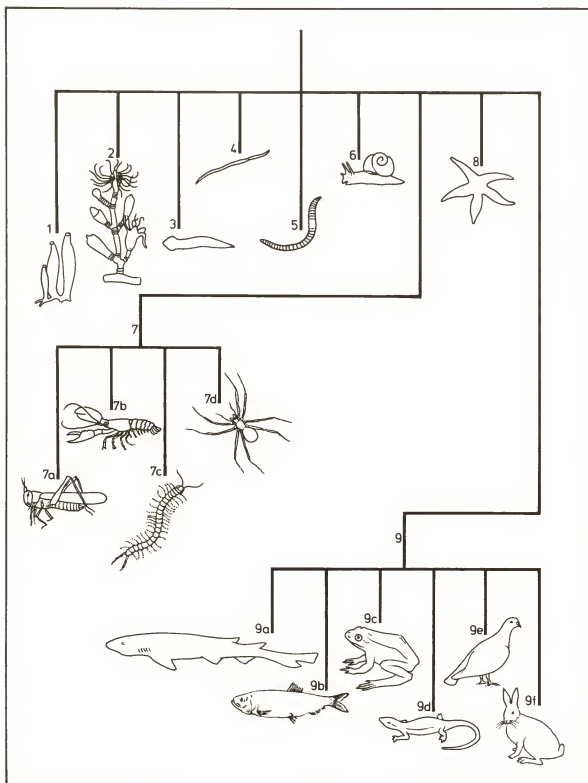
©DIAGRAM

- | | | |
|--------------------------------------|--------------------------------------|---------------------|
| A Flower | 1 Pollen grains (microspores) | 9 Testa |
| B Anther | 2 Pollen tube | 10 Endosperm |
| C Anther - transverse section | 3 σ^7 nuclei | 11 Embryo |
| D Pollen grains released | 4 Tube nucleus | |
| E Pollination | 5 Egg nucleus | |
| F Fertilization | 6 Polar nuclei | |
| G Seed with embryo | 7 Ovule | |
| H Seedling sporophyte | 8 Ovary wall | |

Kingdom Animalia

Classification

03.019



©DIAGRAM

Phyla (sing. -um)

- 1 Porifera
- 2 Coelenterata
- 3 Platyhelminthes
- 4 Nematoda
- 5 Annelida
- 6 Mollusca
- 7 Arthropoda
- 8 Echinodermata
- 9 Chordata

Classes

- 7a Insecta
- 7b Crustacea
- 7c Chilopoda and
Diplopoda
- 7d Arachnida
- 9a Chondrichthyes
- 9b Osteichthyes
- 9c Amphibia
- 9d Reptilia

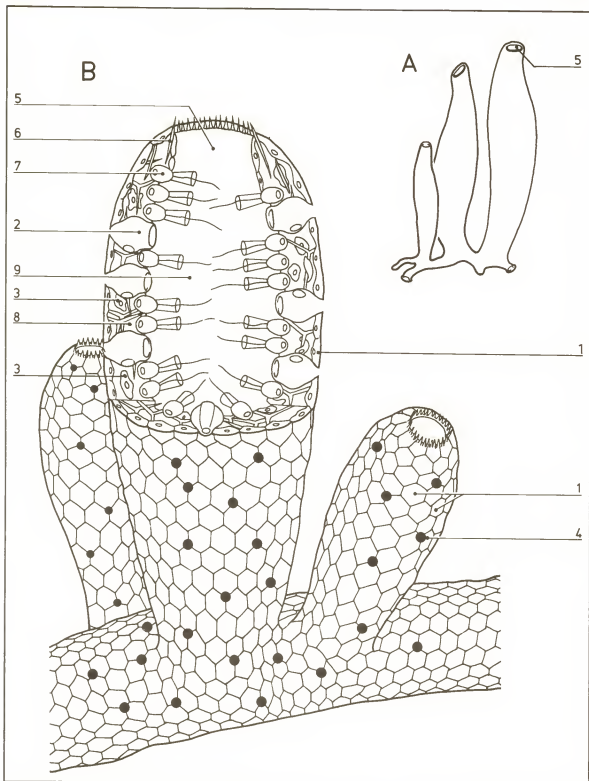
9e Aves

9f Mammalia

Kingdom Animalia

Porifera

03.020



© DIAGRAM

A Colony of ascon-type sponges – external view
B Ascon-type sponge – partially sectioned

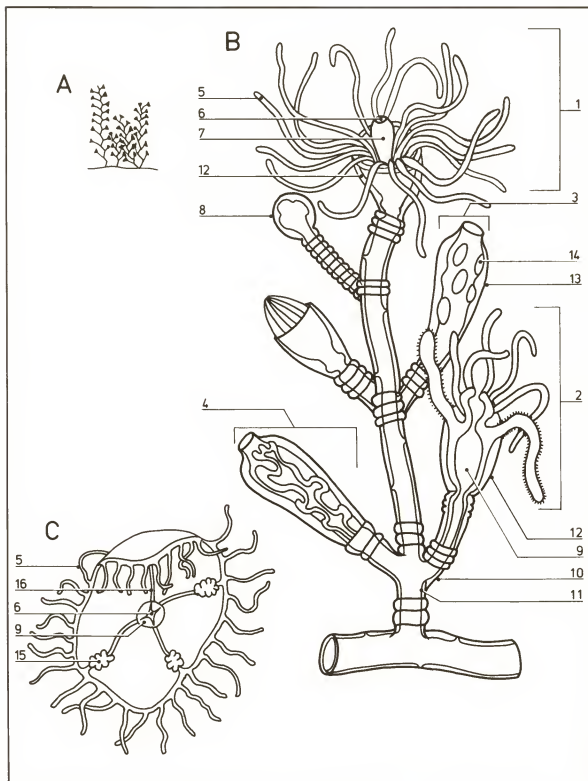
- 7 Choanocyte
- 8 Mesohyal (matrix)
- 9 Spongocoel (paragaster)

- 1 Pinacocytes
- 2 Porocyte
- 3 Amebocyte
- 4 Incurrent pore
- 5 Osculum
- 6 Spicule

Kingdom Animalia

Coelenterata

03.021



©DIAGRAM

A *Obelia* colony as seen with naked eye

B Colonial polyps

C Medusa ♀ – subumbrellar view

1 Feeding polyp (hydranth) – external view

2 Feeding polyp – longitudinal section

3 Reproductive polyp (blastostyle) – external view

4 Reproductive polyp – longitudinal section

5 Tentacle

6 Mouth

7 Hypostome

8 Bud

9 Gastrovascular cavity

10 Perisarc

11 Coenosarc

12 Hydrotheca (cup-shaped)

13 Gonotheca (cylindrical shape)

14 Medusa bud

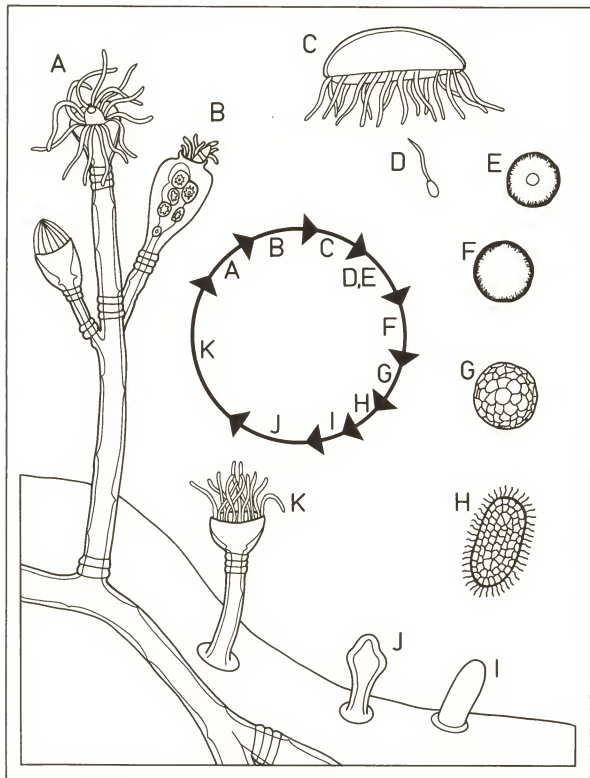
15 Gonad (ovary)

16 Radial canal

Kingdom Animalia

Coelenterata: life cycle

03.022



©DIAGRAM

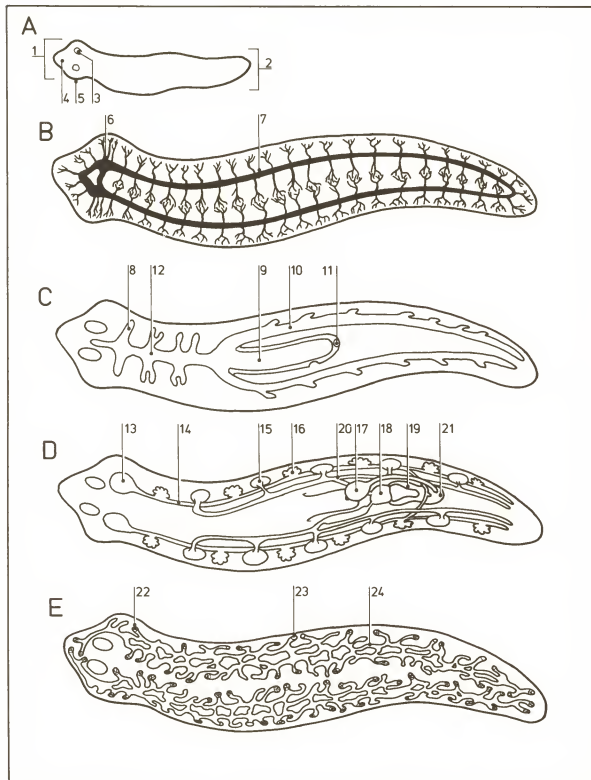
- A *Obelia* sessile colony (asexual stage)
- B Medusa released from blastostyle
- C Free-swimming medusa (sexual stage)
- D Sperm
- E Egg
- F Zygote (fertilized stage)
- G Blastula
- H Ciliated planula larva
- I Larva settles on rock or seaweed

- J Developing polyp
- K Young polyp produces new colony by asexual budding

Kingdom Animalia

Platyhelminthes

03.023



A Turbellarian – dorsal view
B Nervous system
C Digestive system
D Reproductive system
E Excretory system

1 Anterior end
2 Posterior end

3 Eye
4 Head
5 Lateral lobe
6 Cerebral ganglion
7 Ventral nerve cord
8 Gut cecum
9 Pharynx
10 Posterior gut branch
11 Mouth

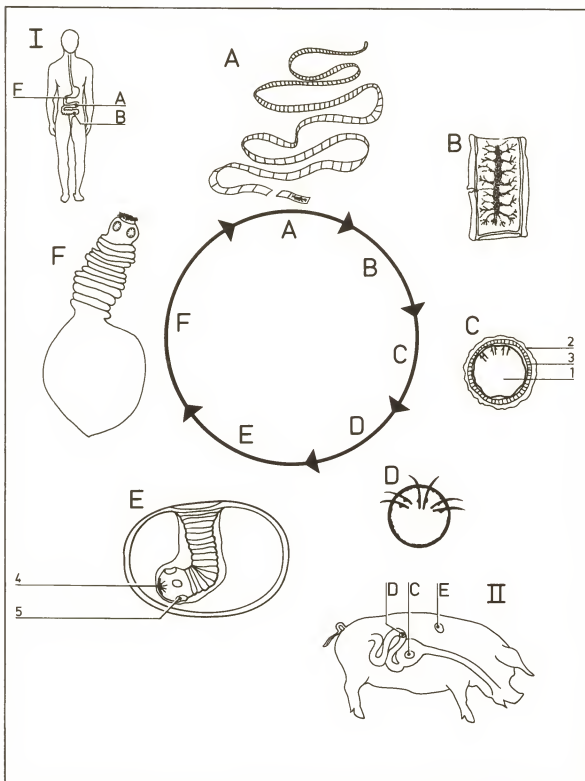
12 Anterior gut branch
13 Ovary
14 Oviduct
15 Testis
16 Yolk sac
17 Copulatory sac
18 Penis
19 Genital chamber
20 Vas deferens

21 Genital pore
22 Flame cell
23 Excretory pore
24 Excretory canal

Kingdom Animalia

Platyhelminthes: life cycle 1

03.024



©DIAGRAM

I Primary host (human)

II Secondary host (pig)

F Cysticercus everts when raw pork is eaten, and develops into tapeworm

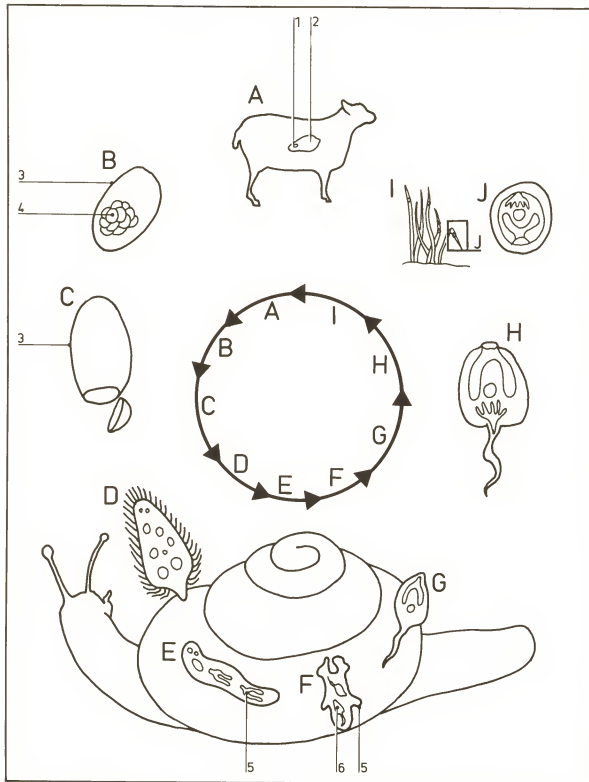
- A Adult *Taenia solium* in human intestine
- B Gravid proglottid in feces containing oncospheres
- C Oncosphere eaten by pig
- D Hexacanth larva released in pig intestine
- E Hexacanth migrates to muscle to form inverted cysticercus

- 1 Hexacanth larva
- 2 Capsule
- 3 Embryophore
- 4 Hooks
- 5 Sucker

Kingdom Animalia

Platyhelminthes: life cycle 2

03.025



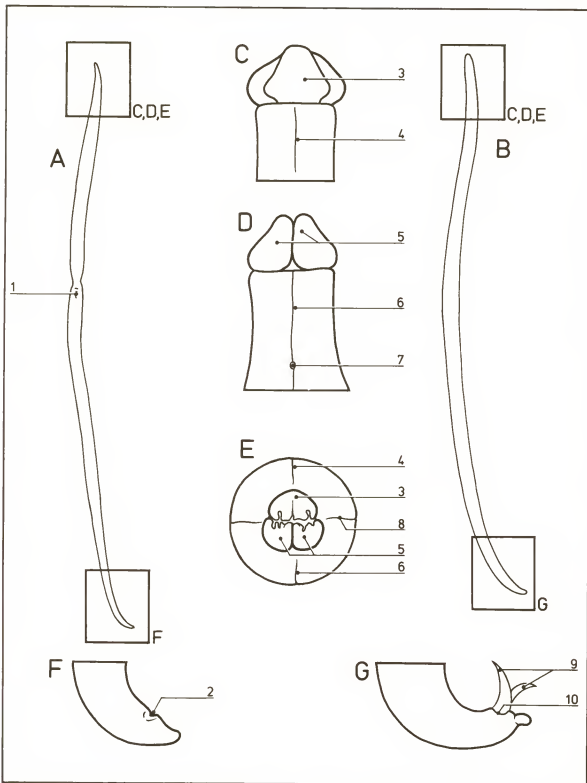
- A Adult liver fluke in sheep bile duct
B Fertilized egg in feces containing developing miracidium
C Egg hatches in water releasing miracidium
D Ciliated miracidium burrows into snail host
E Sporocyst with developing redia
F Redia with developing cercaria
G Cercaria escaping from snail
H Free cercaria

- I Metacercaria encysted on grass, eaten by sheep
J Metacercaria
- 1 Liver fluke
2 Liver
3 Capsule of egg
4 Developing miracidium
5 Redia
6 Cercaria

Kingdom Animalia

Nematoda

03.026



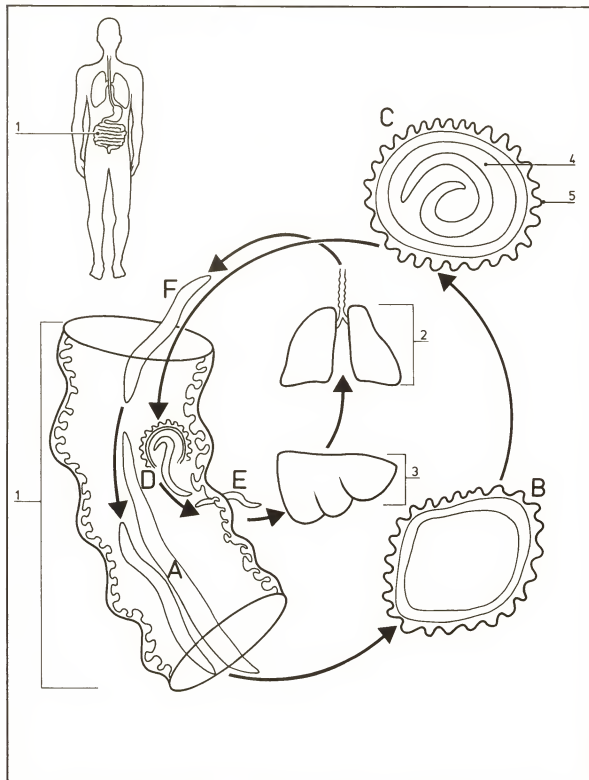
- A *Ascaris lumbricoides* ♀ – external view (ventral)
 B *Ascaris lumbricoides* ♂ – external view
 C Anterior end of worm – dorsal view
 D Anterior end of worm – dorsal view
 E Lips – anterior view
 F Posterior end of ♀ – lateral view
 G Posterior end of ♂ – lateral view

- 1 Genital aperture
 2 Anus
 3 Dorsal lip
 4 Dorsal line
 5 Ventral lip
 6 Ventral line
 7 Excretory pore
 8 Lateral line
 9 Copulatory spicules
 10 Cloacal aperture

Kingdom Animalia

Nematoda: life cycle

03.027



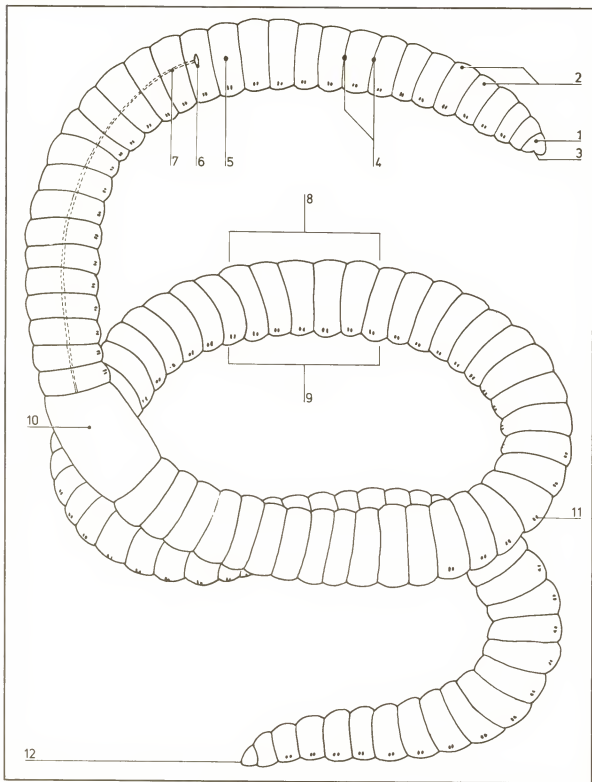
- A *Ascaris lumbricoides* adults in human intestine
 B Egg passes out in feces
 C Infective larva develops within egg
 D Egg eaten by man; larva hatches in intestine
 E Larva passes through gut wall into bloodstream
 F Larva having passed through liver and lungs is coughed up and swallowed

- 1 Human gut
 2 Human lungs
 3 Human liver
 4 Larva
 5 Egg capsule

Kingdom Animalia

Annelida

03.028



Earthworm – lateral view

1 Prostomium

2 Segments

3 Mouth

4 Spermathecal openings

5 Oviduct opening

6 Vas deferens opening

7 Sperm groove

8 Dorsal surface

9 Ventral surface

10 Clitellum

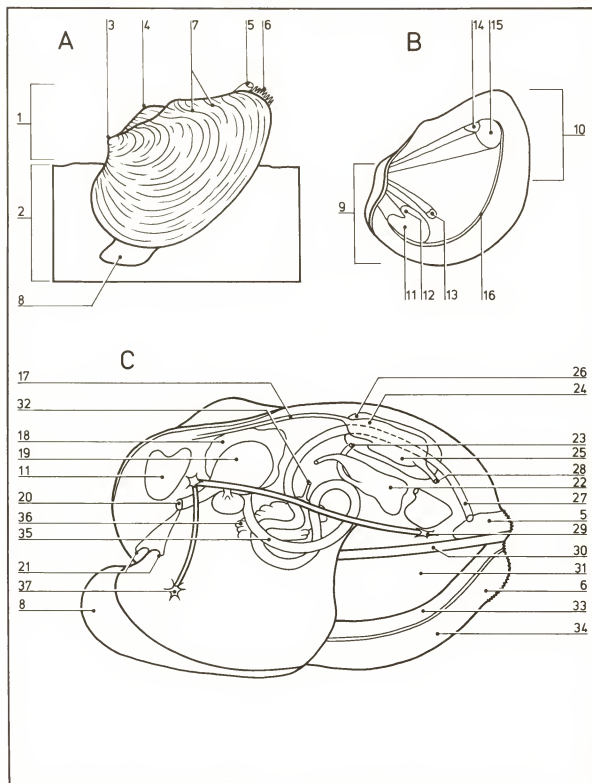
11 Setae

12 Anus

Kingdom Animalia

Mollusca 1

03.029



A External view of left side
B Inside of right valve
C Internal structure (left side removed)

1 Water
2 Mud
3 Umbo
4 Hinge
5 Exhalant siphon

6 Inhalant siphon
7 Growth lines
8 Foot
9 Anterior
10 Posterior
11 Anterior adductor
12 Anterior retractor
13 Anterior protractor
14 Posterior retractor
15 Posterior adductor
16 Pallial line

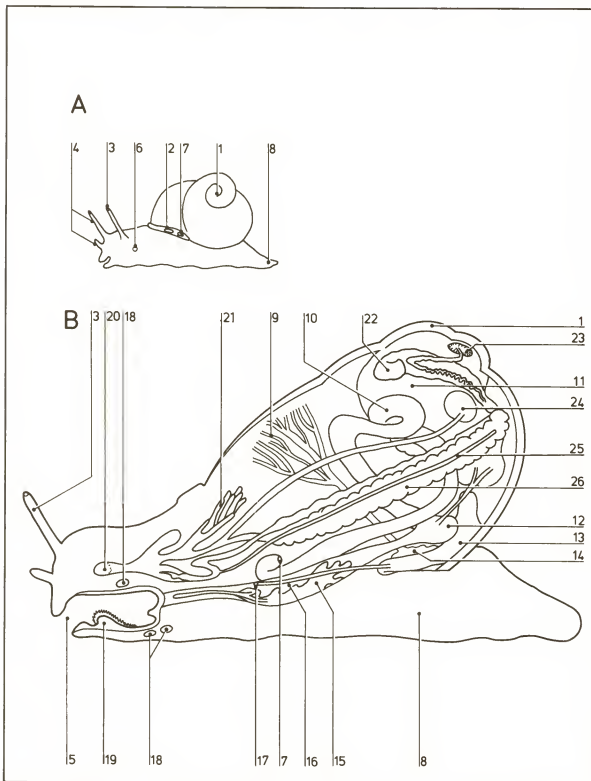
17 Anterior aorta
18 Liver
19 Stomach
20 Mouth
21 Palps
22 Kidney
23 Reno-pericardial opening
24 Ventricle
25 Auricle
26 Pericardium

27 Rectum
28 Posterior aorta
29 Visceral ganglion
30 Suprabranchial chamber
31 Right gill
32 Genital opening
33 Mantle
34 Shell
35 Intestine
36 Gonad
37 Pedal ganglion

Kingdom Animalia

Mollusca 2

03.030



A Snail - lateral view
B Snail - internal structure

- 1 Shell
- 2 Respiratory pore
- 3 Eye
- 4 Tentacles
- 5 Mouth

- 6 Reproductive opening
- 7 Anus
- 8 Foot
- 9 Lung
- 10 Intestine
- 11 Digestive gland (liver)
- 12 Stomach
- 13 Kidney
- 14 Heart

- 15 Salivary gland
- 16 Crop
- 17 Excretory pore
- 18 Ganglia
- 19 Radula
- 20 Gonopore
- 21 Mucous gland
- 22 Albumen gland
- 23 Ovotestis

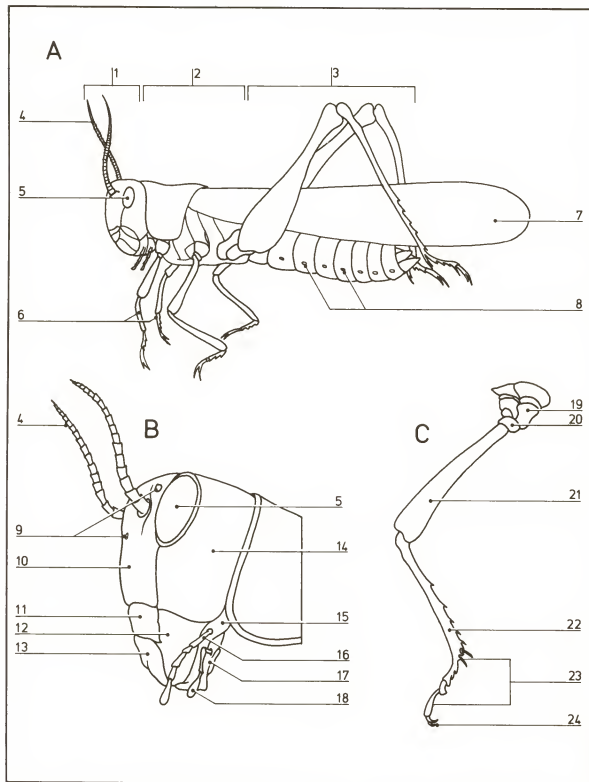
- 24 Seminal receptacle
- 25 Vas deferens
- 26 Oviduct

©DIAGRAM

Kingdom Animalia

Insecta

03.031



© DIAGRAM

Orthoptera – grasshopper

A Lateral view

B Lateral view of head

C Leg

1 Head

2 Thorax

3 Abdomen

4 Antenna

5 Compound eye

6 Legs

7 Forewing

8 Spiracles

9 Ocelli

10 Frons

11 Clypeus

12 Mandible

13 Labrum

14 Gena

15 Maxilla

16 Maxillary palp

17 Labium

18 Labial palp

19 Coxa

20 Trochanter

21 Femur

22 Tibia

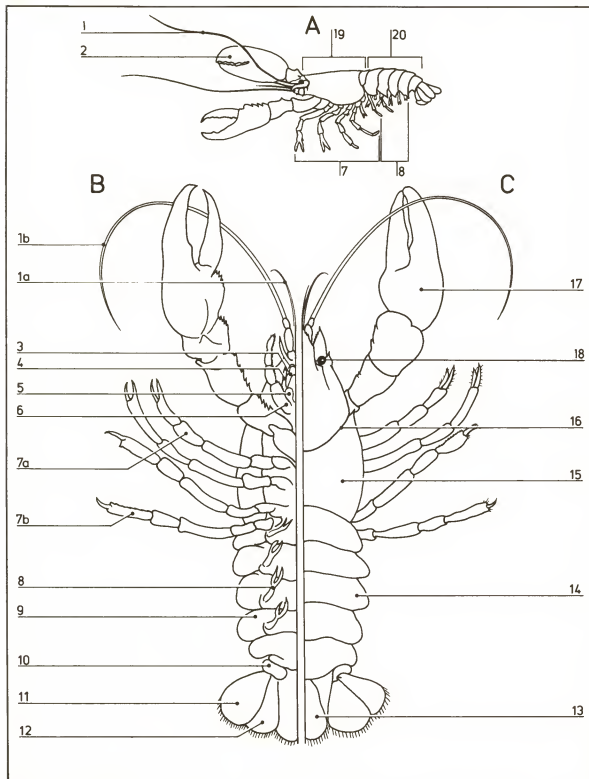
23 Tarsus

24 Pretarsus

Kingdom Animalia

Crustacea

03.032



Malacostraca (*Astacus*)

A Lateral view

B Ventral view

C Dorsal view

1 Antenna

1a First antenna

1b Second antenna

2 Chela

3 Labrum

4 Palp of mandible

5 Mandible

6 Third maxilliped

7 Walking legs

7a First pereiopod

7b Fourth pereiopod

8 Pleopods

9 Sternite (ventral

exoskeleton)

10 Uropod protopodite

11 Uropod exopodite

12 Uropod endopodite

13 Telson

14 Tergite (dorsal

exoskeleton)

15 Carapace

16 Cephalic groove

17 Cheliped

18 Compound eye

19 Cephalothorax

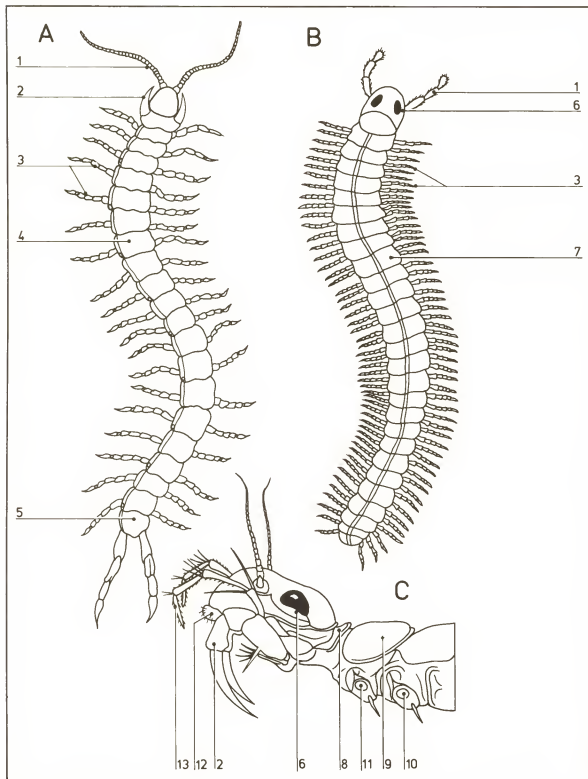
20 Abdomen

©DIAGRAM

Kingdom Animalia

Chilopoda and diplopoda

03.033



© DIAGRAM

A Chilopoda (*Scolopendra*) – dorsal view
B Diplopoda (*Millipede*) – external view
C Chilopoda (*Scutigera*) – lateral view of head

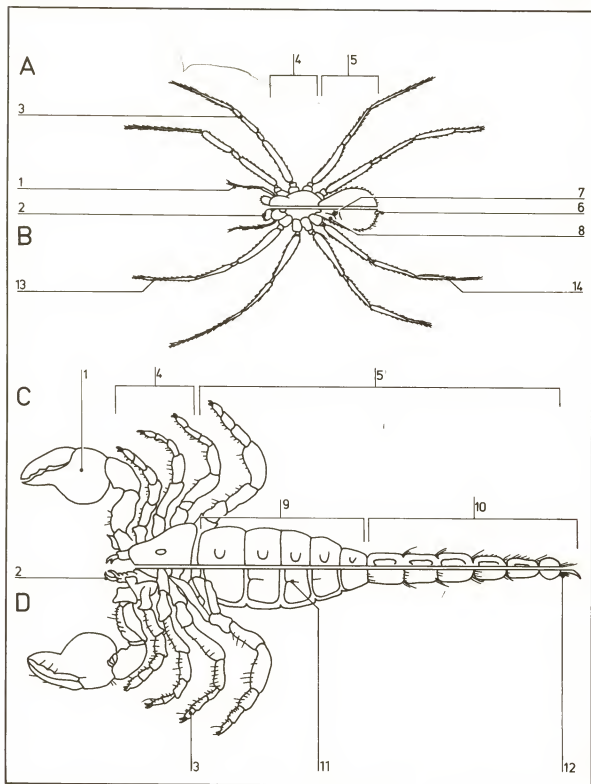
- 1 Antenna
- 2 Maxilliped (poison claw)
- 3 Legs (jointed)
- 4 Tergal plate
- 5 Telson

- 6 Eyes
- 7 Diplosegment
- 8 First tergal plate
- 9 Second tergal plate
- 10 Second leg
- 11 First leg
- 12 First maxilla
- 13 Second maxilla

Kingdom Animalia

Arachnida

03.034



- A Araneae (spider) – dorsal view
B Araneae (spider) – ventral view
C Scorpiones (*Pandinus*) – dorsal view
D Scorpiones (*Pandinus*) – ventral view

- 1 Pedipalp
2 Chelicera
3 Walking leg
4 Prosoma

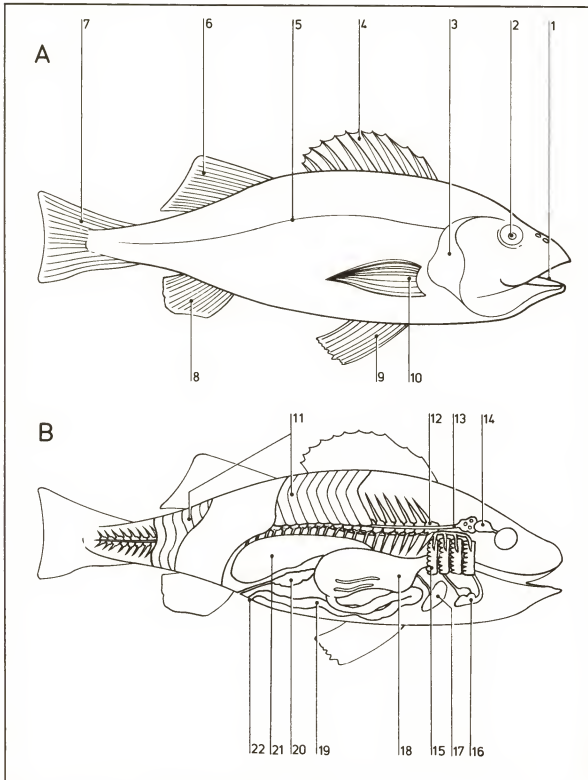
- 5 Opisthosoma
6 Spinneret
7 Genital pore
8 Lung book opening
9 Mesosoma
10 Metasoma
11 Spiracle of book lung
12 Sting
13 First walking leg
14 Fourth walking leg

©DIAGRAM

Kingdom Animalia

Osteichthyes

03.037



©DIAGRAM

Perch

A Lateral view

B Internal structure

- 1 Mouth
- 2 Eye
- 3 Operculum
- 4 Anterior dorsal fin
- 5 Lateral line

6 Posterior dorsal fin

- 7 Caudal fin
- 8 Anal fin
- 9 Pelvic fin
- 10 Pectoral fin
- 11 Muscles
- 12 Vertebrae
- 13 Nerve cord
- 14 Brain

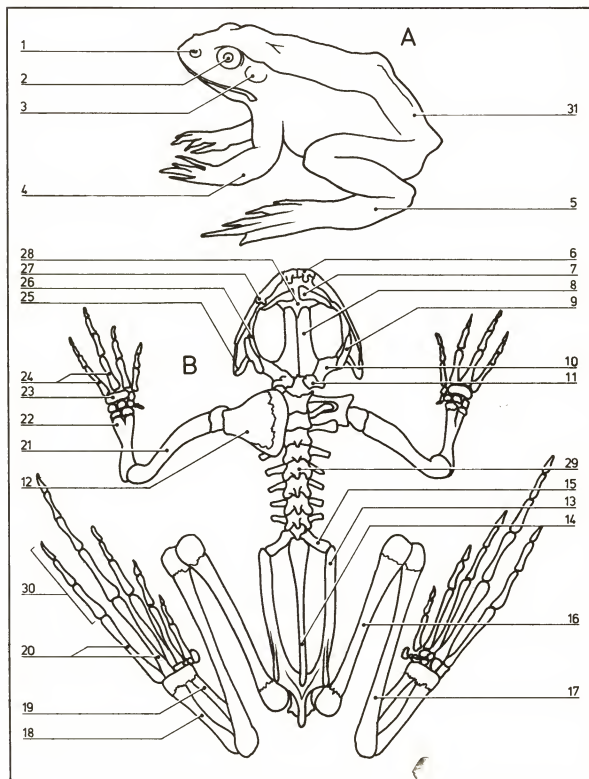
15 Gill

- 16 Heart
- 17 Liver
- 18 Stomach
- 19 Intestine
- 20 Gonads (ovary or testes)
- 21 Swim bladder
- 22 Anus

Kingdom Animalia

Amphibia

03.038



Rana

A External view
B Skeleton

- 1 Nostril
- 2 Eye
- 3 Tympanum
- 4 Fore limb
- 5 Hind limb

- 6 Premaxilla
- 7 Nasal
- 8 Fronto-parietal
- 9 Squamosal
- 10 Prootic
- 11 Exoccipital
- 12 Suprascapular
- 13 Ilium
- 14 Urostyle

- 15 Sacral vertebra
- 16 Femur
- 17 Tibio-fibula
- 18 Calcaneum
- 19 Astragalus
- 20 Metatarsals
- 21 Humerus
- 22 Radio-ulna
- 23 Carpus

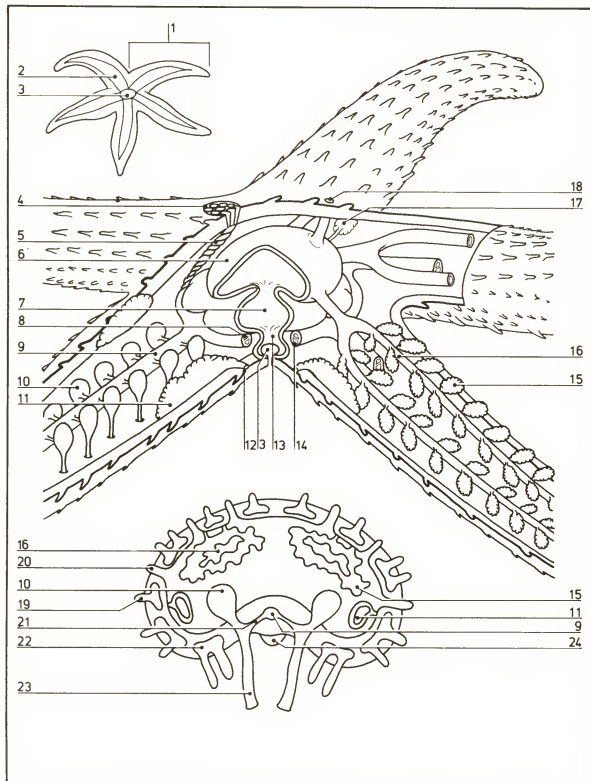
- 24 Metacarpals
- 25 Quadratojugal
- 26 Pterygoid
- 27 Maxilla
- 28 Sphenethmoid
- 29 Vertebra
- 30 Phalanges
- 31 Moist skin

© DIAGRAM

Kingdom Animalia

Echinodermata

03.035



Asteroidea (Asterias)

A Oral view

B Aboral dissection

C Transverse section of arm

1 Arm

2 Ambulacral groove

3 Mouth

4 Madreporite

5 Stone canal

6 Pyloric stomach

7 Cardiac stomach

8 Haemal canal

9 Radial canal

10 Ampulla

11 Gonad

12 Gonopore

13 Esophagus

14 Ring canal

15 Digestive gland

16 Pyloric cecum

17 Rectal sac

18 Anus

19 Spine

20 Papula (gill)

21 Lateral canal

22 Ossicle

23 Tube foot

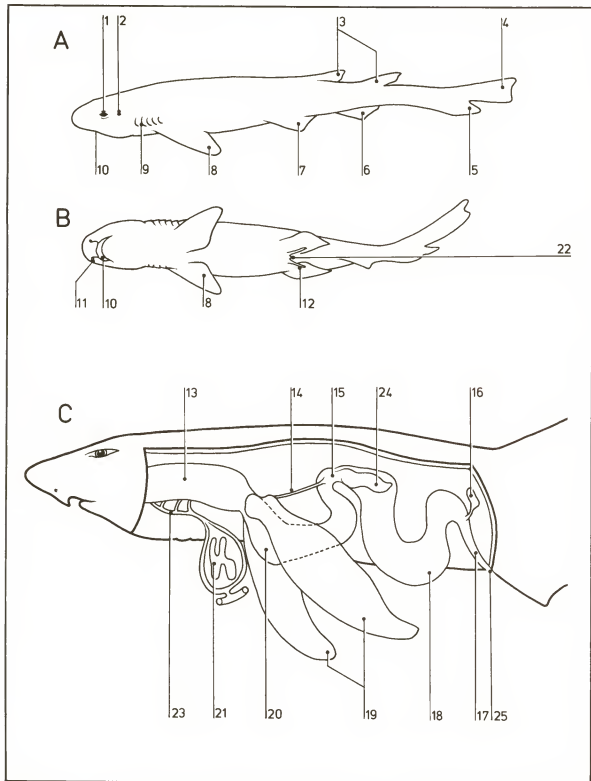
24 Radial nerve

©DIAGRAM

Kingdom Animalia

Chondrichthyes

03.036



Scyliorhinus

A Lateral view

B ♂ - ventral view

C Lateral dissection

1 Eye

2 Spiracle

3 Dorsal fins

4 Caudal fin - upper lobe

5 Caudal fin - lower lobe

6 Ventral fin

7 Pelvic fin

8 Pectoral fin

9 Gill slits

10 Mouth

11 Nostril

12 Clasper

13 Pharynx

14 Bile duct

15 Pancreatic duct

16 Rectal gland

17 Rectum

18 Intestine

19 Liver

20 Stomach

21 Heart

22 Cloaca

23 Ventral aorta

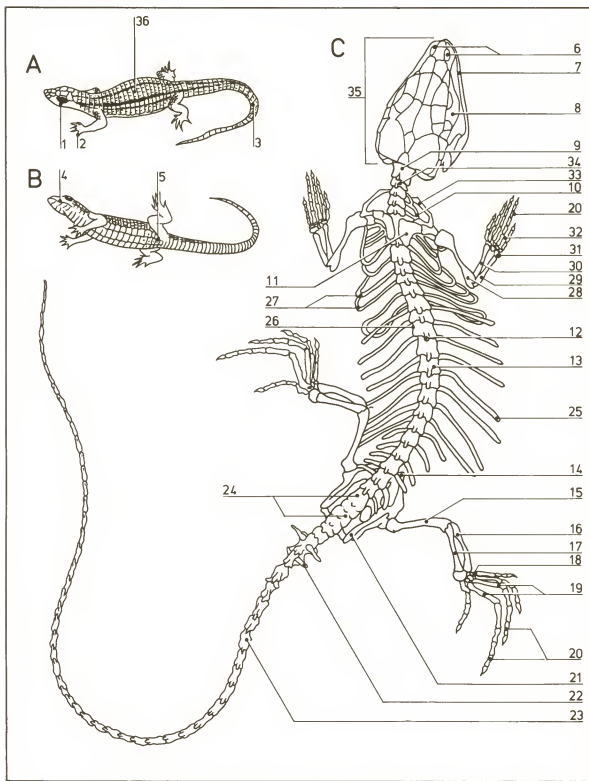
24 Pancreas

25 Anus

Kingdom Animalia

Reptilia

03.039



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Lacerta

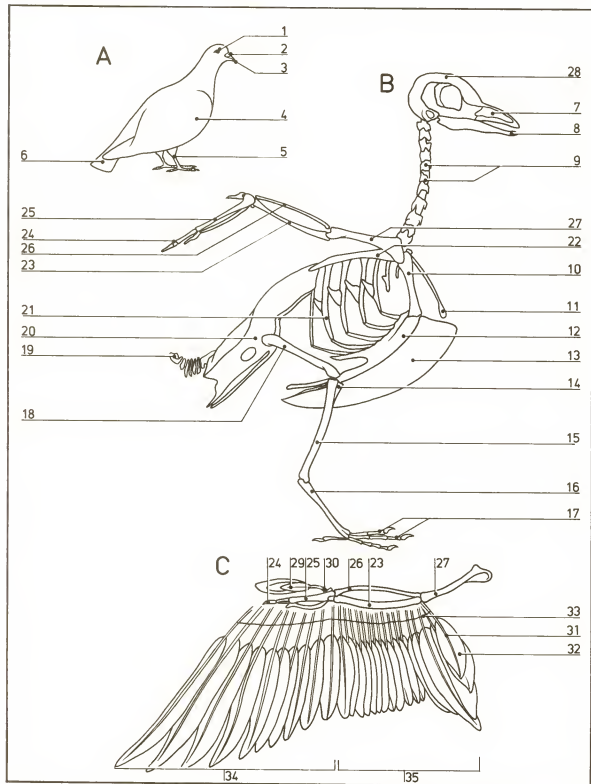
- A Dorsal view
B Ventral view
C Dorsal view of skeleton

- | | | | |
|----------|------------------|-----------------------|--------------------------|
| 1 Eye | 6 External nares | 16 Fibula | 26 Vertebrae |
| 2 Digits | 7 Lower jaw | 17 Tibia | 27 Rib cage |
| 3 Tail | 8 Orbit | 18 Tarsus | 28 Humerus |
| 4 Mouth | 9 Axis vertebra | 19 Metatarsals | 29 Ulna |
| 5 Cloaca | 10 Cervical ribs | 20 Phalanges | 30 Radius |
| | 11 Suprascapular | 21 Ilium | 31 Carpals |
| | 12 Neural spine | 22 Transverse process | 32 Metacarpals |
| | 13 Neural arch | 23 Caudal vertebrae | 33 Clavicle |
| | 14 Pubis | 24 Sacral vertebrae | 34 Cervical vertebrae |
| | 15 Femur | 25 Rib | 35 Skull |
| | | | 36 Scutes (horny scales) |

Kingdom Animalia

Aves

03.040



©DIAGRAM

Columba

A External view

B Skeleton

C Wing

1 Eye

2 Cere

3 Beak

4 Wing

5 Hind limbs

6 Retrices

7 Upper mandible

8 Lower mandible

9 Cervical vertebrae

10 Coracoid

11 Clavicle

12 Sternum

13 Keel of sternum

14 Fibula

15 Tibio-tarsus

16 Fused tarsi and metatarsi

17 Phalanges

18 Femur

19 Pygostyle

20 Pelvis

21 Rib

22 Scapula

23 Ulna

24 Second digit

25 Carpo-metacarpus

26 Radius

27 Humerus

28 Skull

29 Alula

30 First digit

31 Rachis

32 Vane

33 Ligament

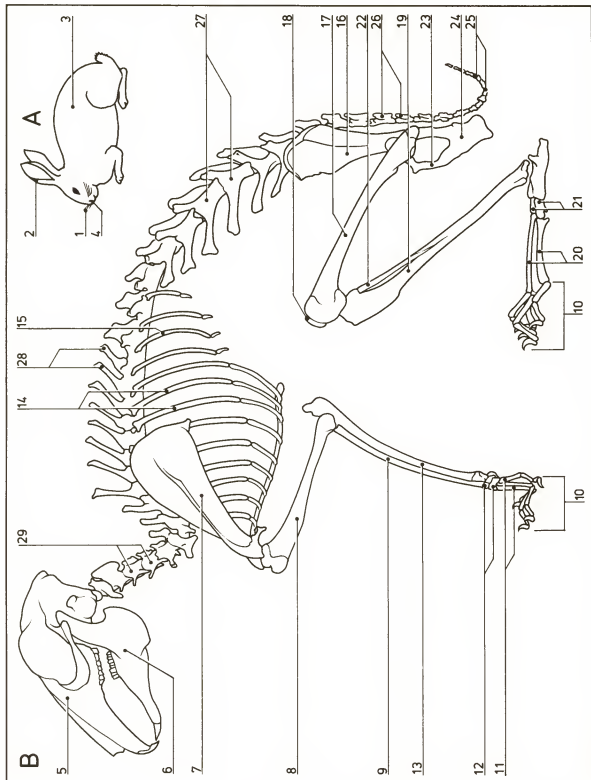
34 Primaries

35 Secondaries

Kingdom Animalia

Mammalia

03.041



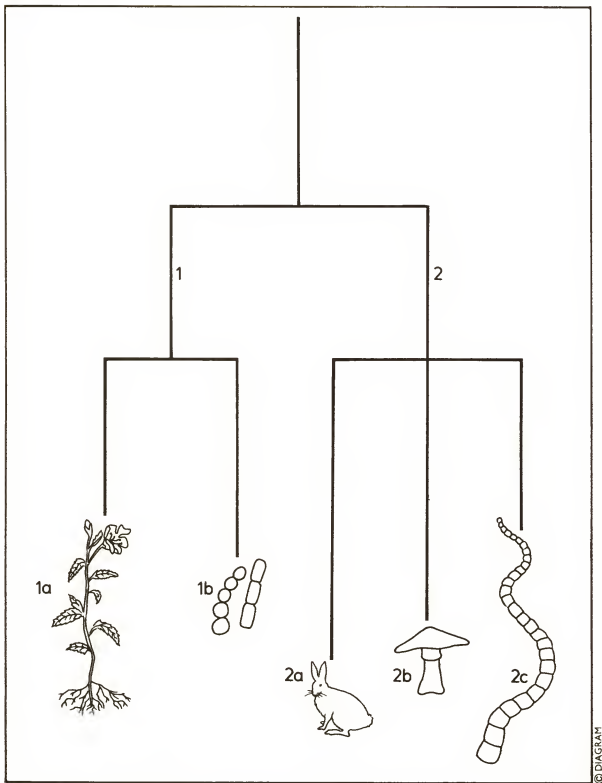
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Oryctolagus
A External view
B Lateral view of skeleton

- 1 Whiskers
- 2 Pinna
- 3 Fur
- 4 Nostril
- 5 Skull
- 6 Lower jaw
- 7 Scapula
- 8 Humerus
- 9 Radius
- 10 Phalanges
- 11 Metacarpals
- 12 Carpals
- 13 Ulna
- 14 Ribs
- 15 Floating ribs
- 16 Ilium
- 17 Femur
- 18 Patella
- 19 Tibia
- 20 Metatarsals
- 21 Tarsals
- 22 Fibula
- 23 Ischium
- 24 Pubis
- 25 Caudal vertebrae
- 26 Sacral vertebrae
- 27 Lumbar vertebrae
- 28 Thoracic vertebrae
- 29 Cervical vertebrae

Nutrition: types

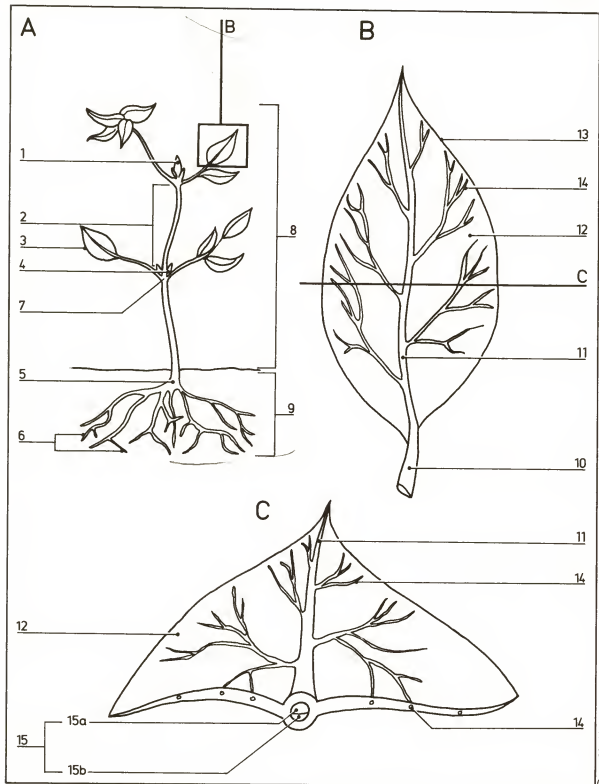
04.001



- 1 Autotrophic (use of light energy)
- 1a Photoautotrophic (green plants, some protists, purple sulfur bacteria)
- 1b Chemoautotrophic (nitrogen cycle bacteria)
- 2 Heterotrophic (use chemical energy)
- 2a Holozoic (most animals, carnivorous plants, some protists)
- 2b Saprotrophic (some bacteria, fungi)
- 2c Parasitic (some bacteria, fungi, protists, animals, plants)

Nutrition: leaf structure 1

04.002



A Typical flowering plant (dicotyledon)

B Leaf - surface view

C Leaf - transverse section

1 Apical (terminal) bud

2 Internode

3 Leaf

4 Lateral (axillary) bud

5 Main root

6 Lateral roots

7 Node

8 Shoot

9 Root

10 Petiole (leaf stalk)

11 Midrib

12 Leaf blade (lamina)

13 Margin

14 Vein

15 Vascular bundle

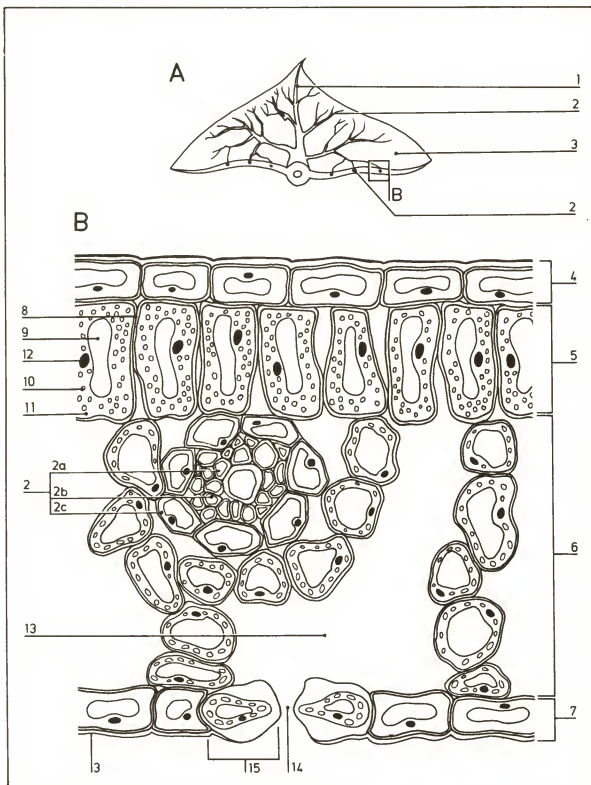
15a Xylem

15b Phloem

© DIAGRAM

Nutrition: leaf structure 2

04.003



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A Leaf – transverse section (low power)
B Leaf – transverse section (high power)

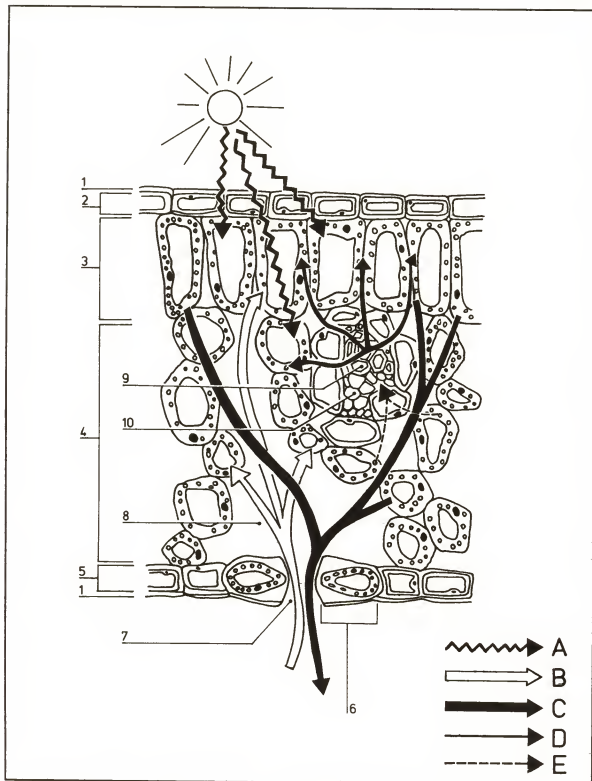
- 1 Midrib
- 2 Vein
- 2a Xylem
- 2b Phloem
- 2c Parenchyma
- 3 Cuticle

- 4 Upper epidermis
- 5 Palisade mesophyll
- 6 Spongy mesophyll
- 7 Lower epidermis
- 8 Cell wall
- 9 Vacuole
- 10 Chloroplast
- 11 Cytoplasm
- 12 Nucleus

- 13 Air space
- 14 Stoma (plural stomata)
- 15 Guard cell

Nutrition: leaf and photosynthesis

04.004



© DIAGRAM

Leaf section showing movement of materials required for or produced by photosynthesis

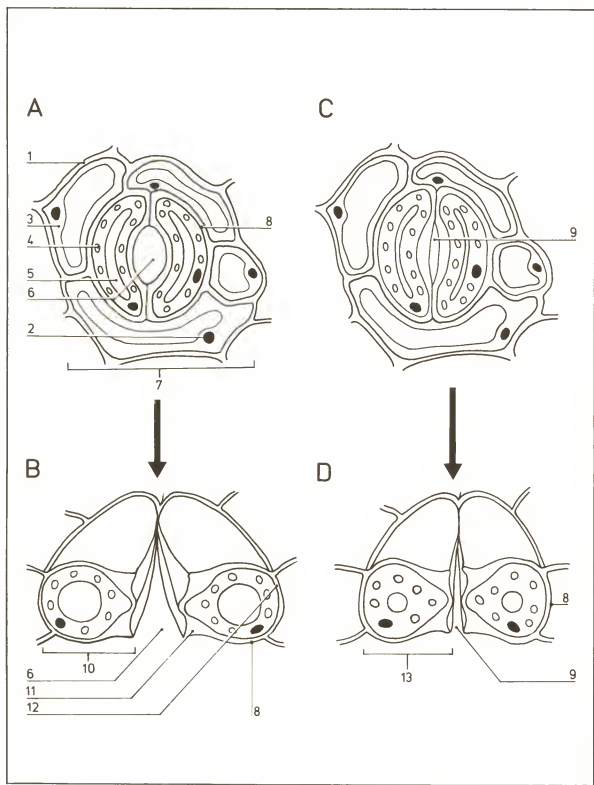
- A Sunlight
- B Carbon dioxide
- C Oxygen
- D Water
- E Glucose

- 1 Cuticle
- 2 Upper epidermis
- 3 Palisade mesophyll
- 4 Spongy mesophyll
- 5 Lower epidermis
- 6 Guard cell
- 7 Stoma
- 8 Air space
- 9 Xylem

10 Phloem

Nutrition: stomata

04.005



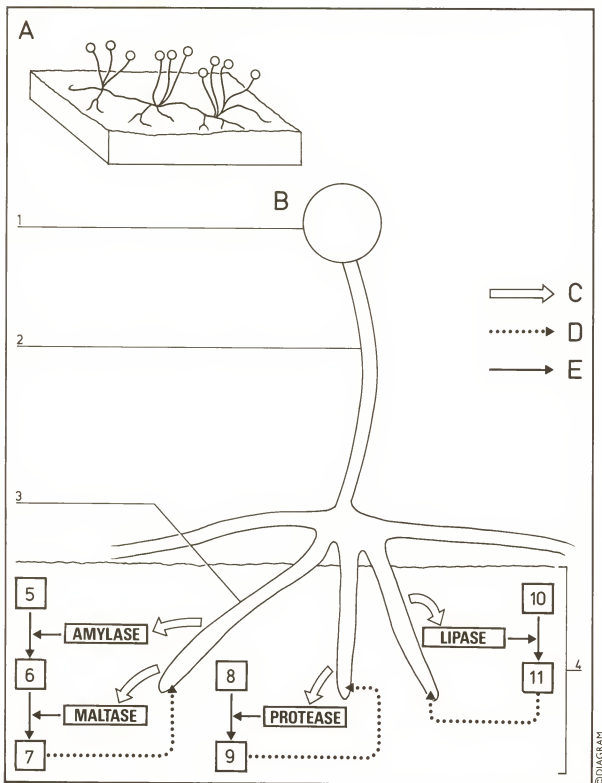
A Stoma open during day - surface view
B Stoma open during day - cross section
C Stoma closed at night - surface view
D Stoma closed at night - cross section

- 1 Cell wall
- 2 Nucleus
- 3 Cytoplasm
- 4 Chloroplast

- 5 Vacuole
- 6 Stoma (open)
- 7 Epidermal cell
- 8 Guard cell
- 9 Stoma (closed)
- 10 Guard cell (turgid)
- 11 Thick cell wall (inner)
- 12 Thin cell wall (outer)
- 13 Guard cell (flaccid)

Nutrition: bread mold

04.006



Saprotrophic nutrition in *Rhizopus*

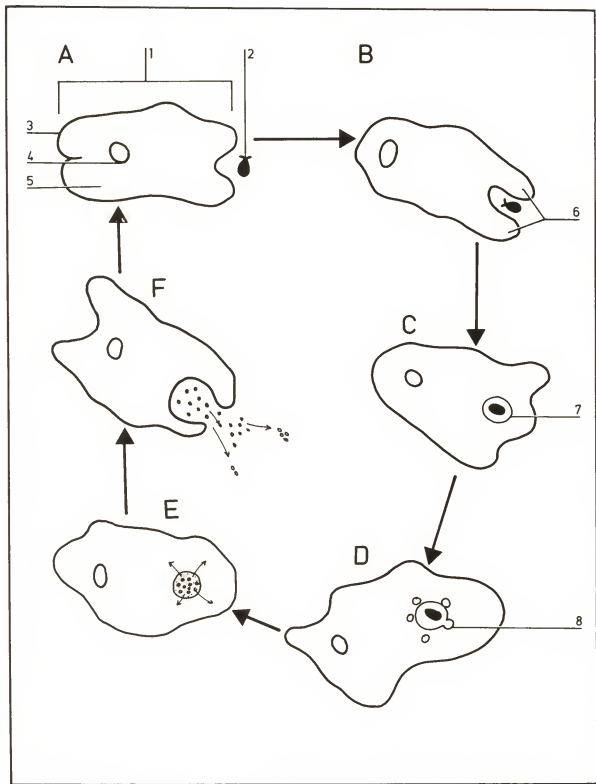
- A *Rhizopus* mycelium growing on bread
 B Detail of mycelium showing extracellular digestion
 C Secretion of enzymes
 D Absorption of products of digestion
 E Enzyme-catalyzed breakdown of substrate (bread)

- 1 Sporangium
 2 Aerial hypha

- 3 Hypha
 4 Substrate (bread)
 5 Starch
 6 Maltose
 7 Glucose
 8 Protein
 9 Amino acids
 10 Fat
 11 Fatty acids and glycerol

Nutrition: Protista

04.007



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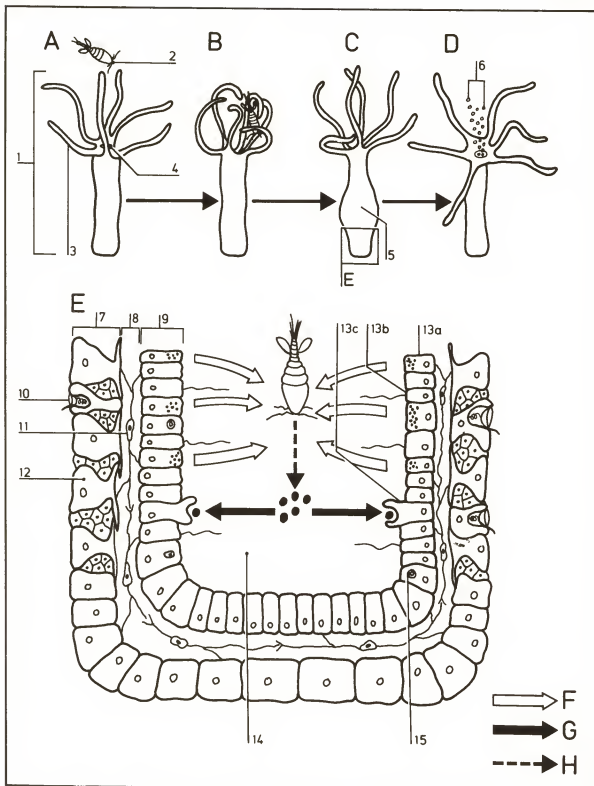
Feeding and intracellular digestion in *Amoeba*

- A Detects prey
- B Ingestion – pseudopodia surround prey
- C Ingestion – food vacuole formed
- D Digestion – lysosomes empty enzymes into food vacuole
- E Absorption of soluble products into cytoplasm
- F Exocytosis of indigestible material

- 1 *Amoeba*
- 2 Prey (alga)
- 3 Cell membrane
- 4 Nucleus
- 5 Cytoplasm
- 6 Pseudopodia
- 7 Food vacuole
- 8 Lysosome emptying enzymes into food vacuole

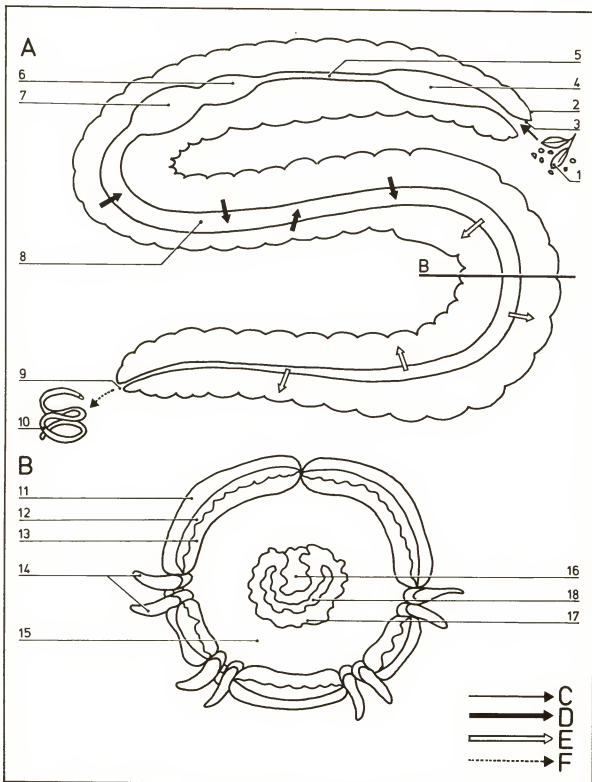
Nutrition: *Hydra*

04.008



Nutrition: earthworm

04.009



- A** Longitudinal section showing gut
B Transverse section through intestinal region
C Ingestion
D Digestion
E Absorption
F Egestion

- 1 Food
 2 Prostomium

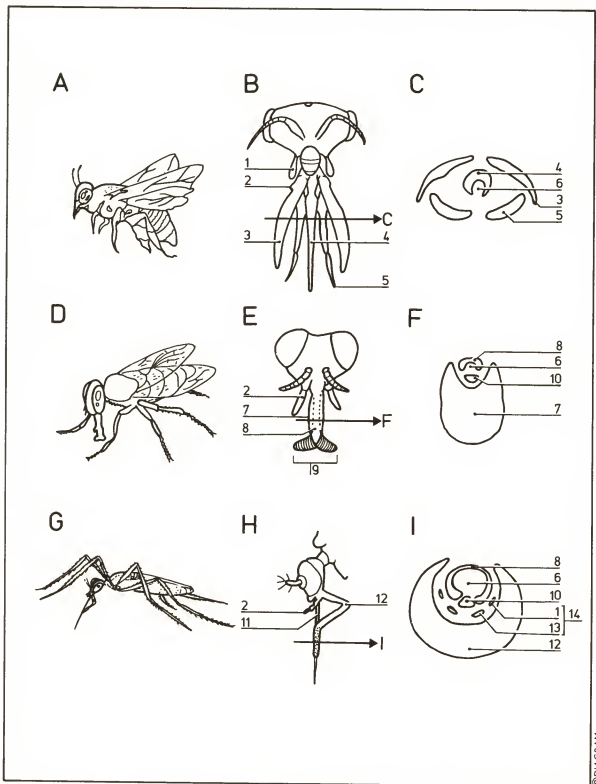
- 3 Mouth
 4 Pharynx (food softening)
 5 Esophagus (food softening)
 6 Crop (food storage)
 7 Gizzard (food grinding)
 8 Intestine (digestion and absorption)
 9 Anus
 10 Waste
 11 Epidermis

- 12 Circular muscles
 13 Longitudinal muscles
 14 Setae
 15 Coelom
 16 Typhlosole
 17 Intestinal wall
 18 Intestinal lumen

©DIAGRAM

Nutrition: insect mouthparts

04.010



A-C Honey bee
A Whole animal
B Head - anterior
C Mouthparts - section
D-F Housefly
D Whole animal
E Head - anterior
F Mouthparts - section
G-I Mosquito

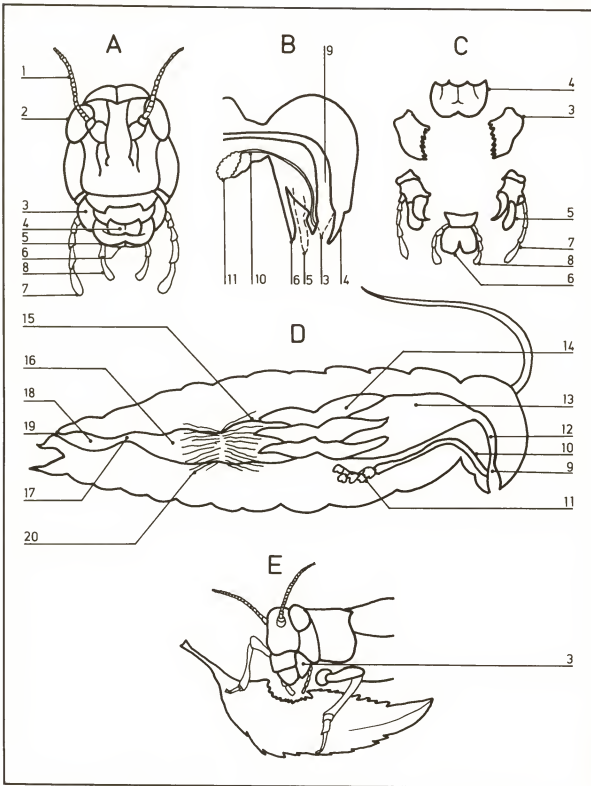
G Whole animal
H Head - lateral
I Mouthparts - section
1 Mandible
2 Maxillary palp
3 Galea
4 Glossa
5 Labial palp

6 Food tube
7 Labium
8 Labrum
9 Expanded end of labium
10 Salivary tube
11 Proboscis
12 Proboscis sheath (labium)

13 Maxilla
14 Stylets

Nutrition: grasshopper

04.011



- A** Head – anterior
B Head – schematic longitudinal section
C Mouthparts
D Body – longitudinal section showing digestive system
E Feeding on vegetation – strong mandibles move from side to side

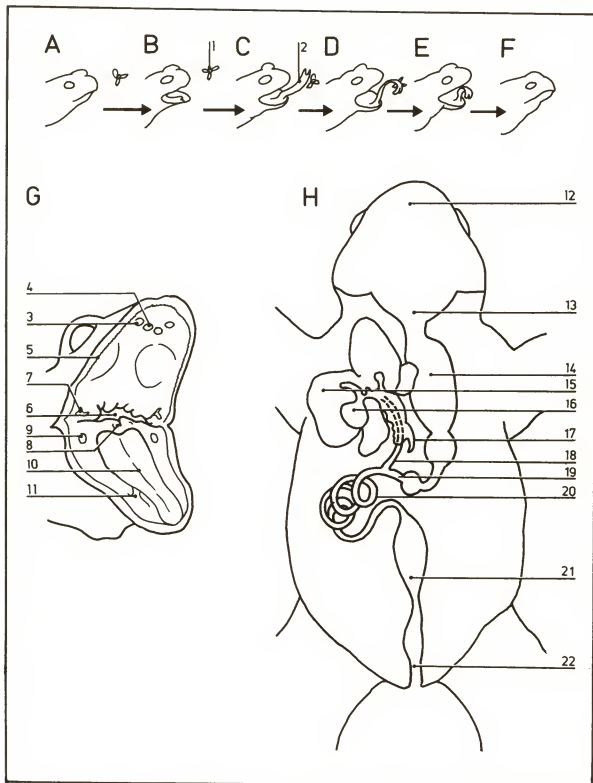
- 1 Antenna
 2 Compound eye

- 3 Mandible
 4 Labrum
 5 Maxilla
 6 Labium
 7 Maxillary palp
 8 Labial palp
 9 Pharynx
 10 Salivary duct
 11 Salivary gland

- 12 Esophagus
 13 Crop
 14 Gastric cecum
 15 Stomach
 16 Large intestine
 17 Colon
 18 Rectum
 19 Anus
 20 Malpighian tubules

Nutrition: frog

04.012



A-F Feeding mechanism

G Mouth

H Gut

1 Fly

2 Tongue

3 Internal nostril opening

4 Vomerine teeth

5 Maxillary teeth

6 Opening of esophagus

7 Opening of Eustachian tube

8 Glottis

9 Vocal sac opening

10 Tongue

11 Attachment of tongue

12 Mouth

13 Esophagus

14 Stomach

15 Liver

16 Gall bladder

17 Pancreas

18 Hepatopancreatic duct

19 Duodenum

20 Ileum

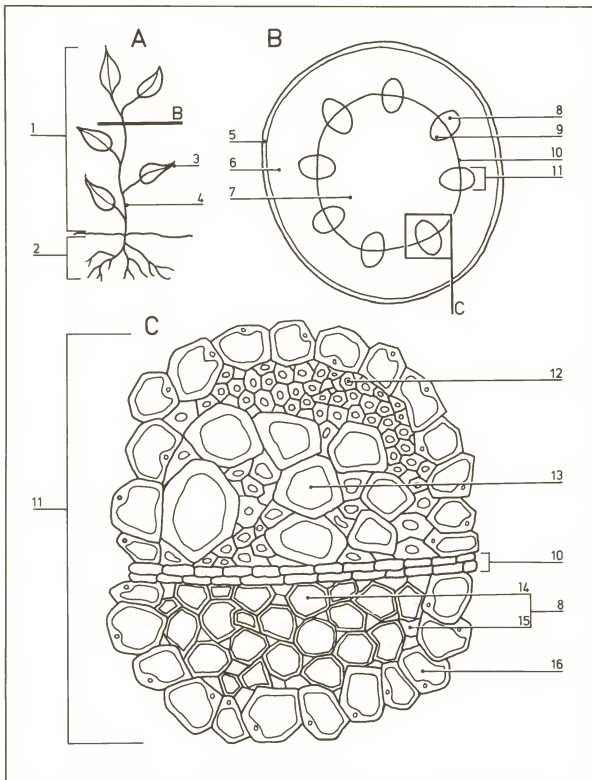
21 Rectum

22 Anus

© DIAGRAM

Transport: stem structure 1

04.013



Dicotyledon stem structure

A Generalized plant
B Stem - transverse

section
C Vascular bundle -

transverse section

1 Shoot
2 Root

3 Leaf

4 Stem

5 Epidermis

6 Cortex (parenchyma)

7 Pith (parenchyma)

8 Phloem

9 Xylem

10 Cambium

11 Vascular bundle

12 Fibers

13 Xylem vessels

14 Sieve tube

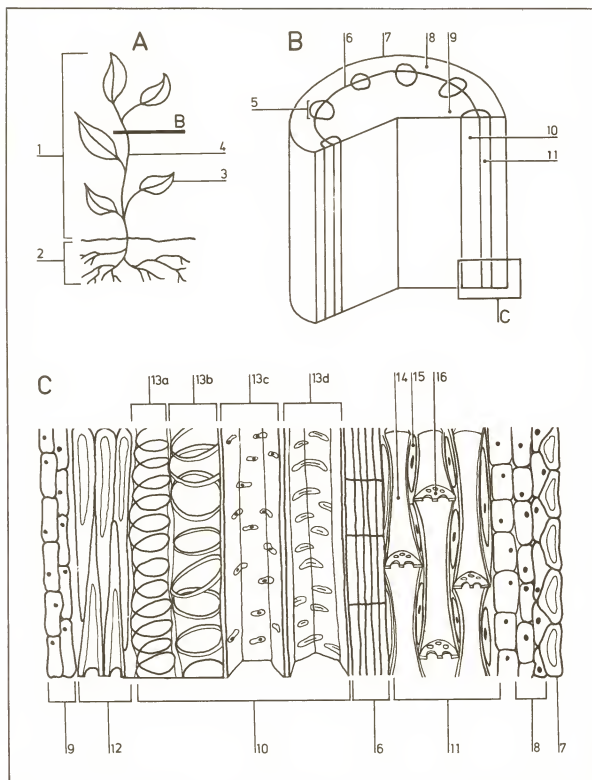
15 Companion cell

16 Parenchyma

©DIAGRAM

Transport: stem structure 2

04.014



Dicotyledon stem structure

A Generalized plant
B Stem - section
C Vascular bundle -
longitudinal section

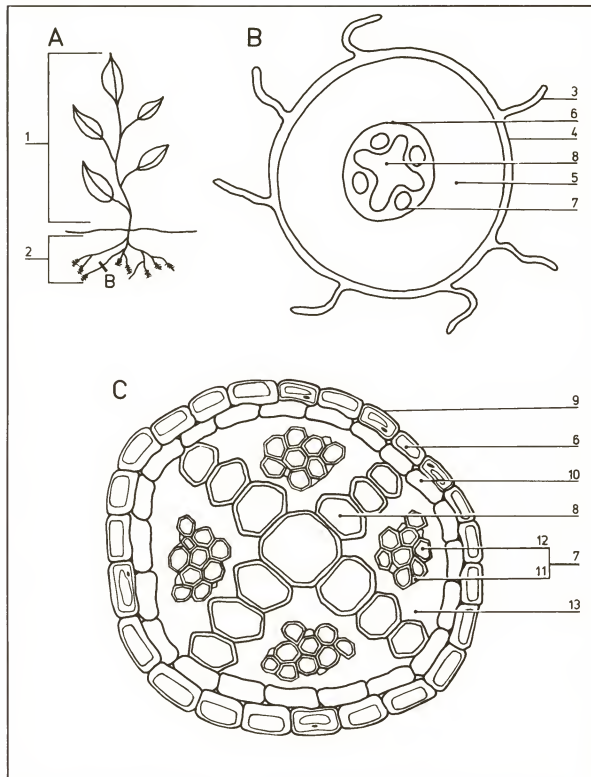
1 Shoot
2 Root
3 Leaf

4 Stem
5 Vascular bundle
6 Cambium
7 Epidermis
8 Cortex (parenchyma)
9 Pith (parenchyma)
10 Xylem
11 Phloem
12 Fibers

13 Xylem vessels
13a Spiral thickening
13b Annular thickening
13c Pitted
13d Reticulate
14 Sieve tube
15 Companion cell
16 Sieve plate

Transport: root structure

04.015



©DIAGRAM

Dicotyledon root structure

A Generalized plant

B Root – transverse section

C Stele – transverse section

1 Shoot

2 Root

3 Root hairs

4 Epidermis

5 Cortex (parenchyma)

6 Endodermis

7 Phloem

8 Xylem

9 Passage cell

10 Stele

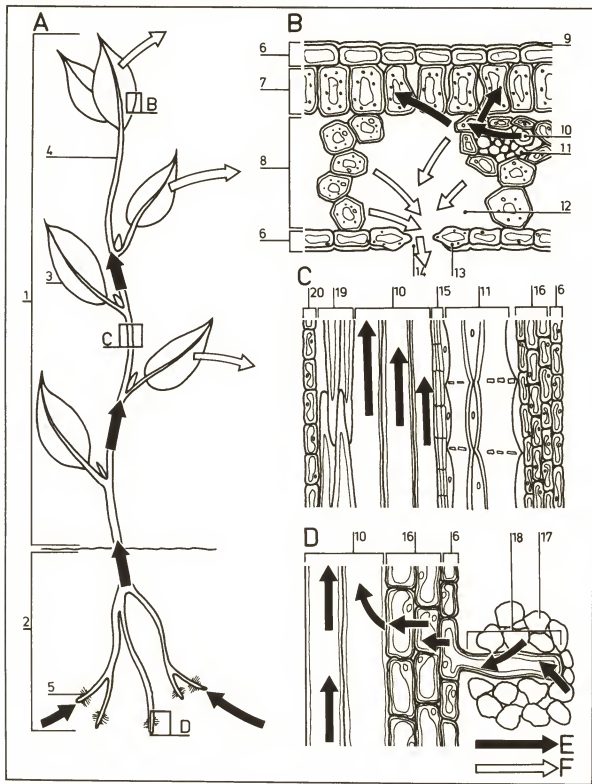
11 Companion cell

12 Sieve tube

13 Space filled with parenchyma

Transport: water and minerals in plants

04.016



- A Generalized plant
- B Leaf - transverse section
- C Stem - longitudinal section
- D Root - longitudinal section
- E Flow of water and minerals
- F Evaporation of water from leaf (transpiration)

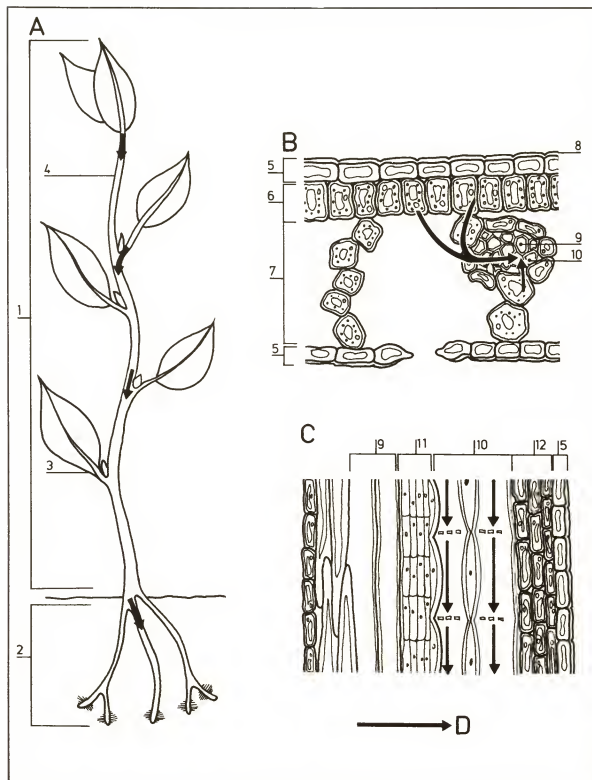
- 1 Shoot
- 2 Root

- 3 Leaf
- 4 Stem
- 5 Root hair
- 6 Epidermis
- 7 Palisade mesophyll
- 8 Spongy mesophyll
- 9 Cuticle
- 10 Xylem
- 11 Phloem

- 12 Air space
- 13 Guard cell
- 14 Stoma
- 15 Cambium
- 16 Parenchyma (cortex)
- 17 Soil particles
- 18 Root hair
- 19 Fibers
- 20 Pith

Transport: food in plants

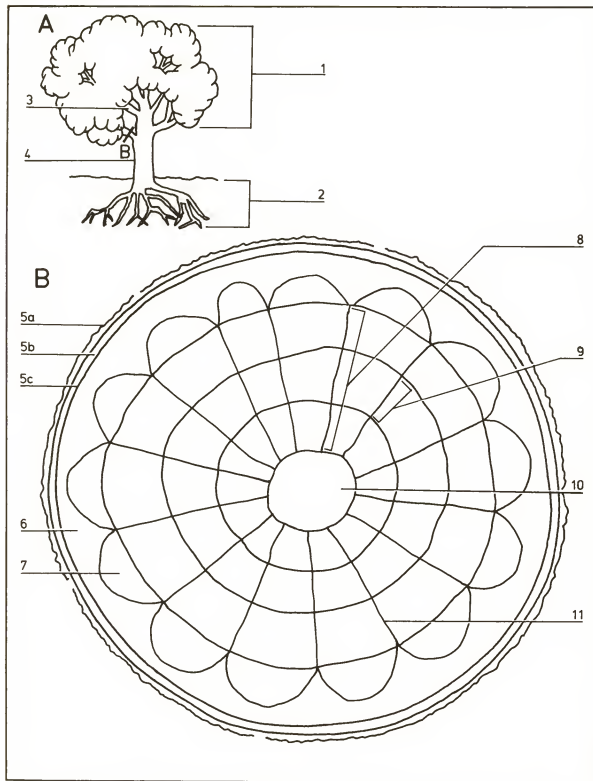
04.017



- A Generalized plant
B Leaf - transverse section
C Stem - longitudinal section
D Flow of food
- 1 Shoot
2 Root
3 Leaf
4 Stem
5 Epidermis
6 Palisade mesophyll
7 Spongy mesophyll
8 Cuticle
9 Xylem
10 Phloem
11 Cambium
12 Parenchyma

Transport: woody stem

04.018



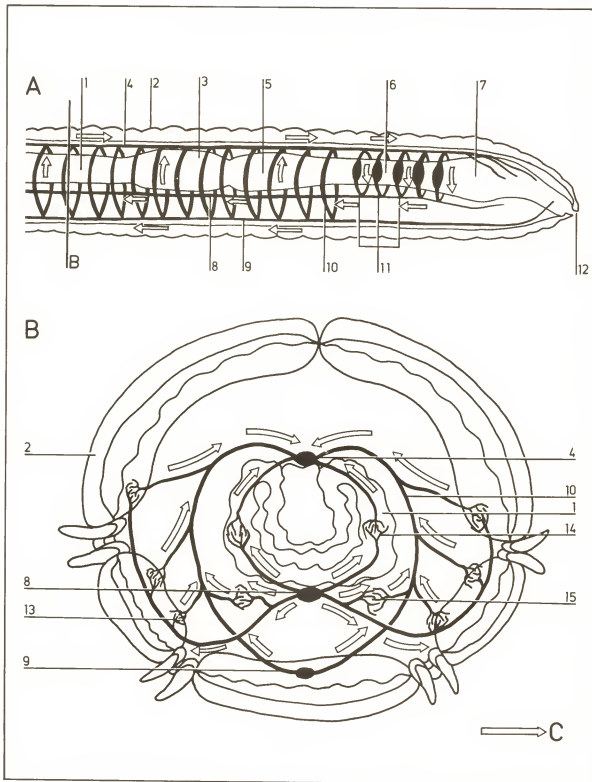
A Generalized tree
B Branch – transverse
section

1 Canopy (foliage)
2 Roots
3 Branch
4 Trunk
5 Bark

5a Remains of epidermis
5b Cork
5c Cork cambium
6 Cortex
7 Secondary phloem
8 Secondary xylem
(wood)
9 Annual ring growth
10 Pith
11 Vascular ray

Transport: earthworm

04.019



- A** Anterior end – longitudinal section to show main blood vessels
- B** Intestinal region – schematic transverse section to show relationship between main blood vessels

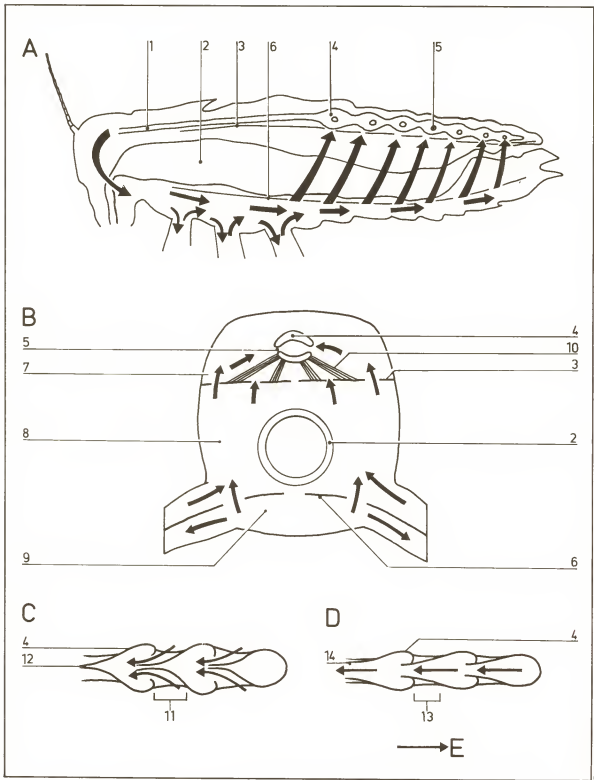
C Direction of flow

- 1 Intestine
- 2 Epidermis
- 3 Gizzard
- 4 Dorsal vessel
- 5 Crop
- 6 Esophagus
- 7 Pharynx
- 8 Ventral vessel
- 9 Subneural vessel
- 10 Commissural of parietal vessel
- 11 Aortic arches (pseudo-hearts)
- 12 Mouth
- 13 Body wall capillaries
- 14 Intestinal capillaries

- 15 Nephridial capillaries

Transport: grasshopper

04.020



© DIAGRAM

A Longitudinal section showing circulatory system

B Transverse section showing circulatory system

C & D Part of heart – longitudinal section

C Alary muscles

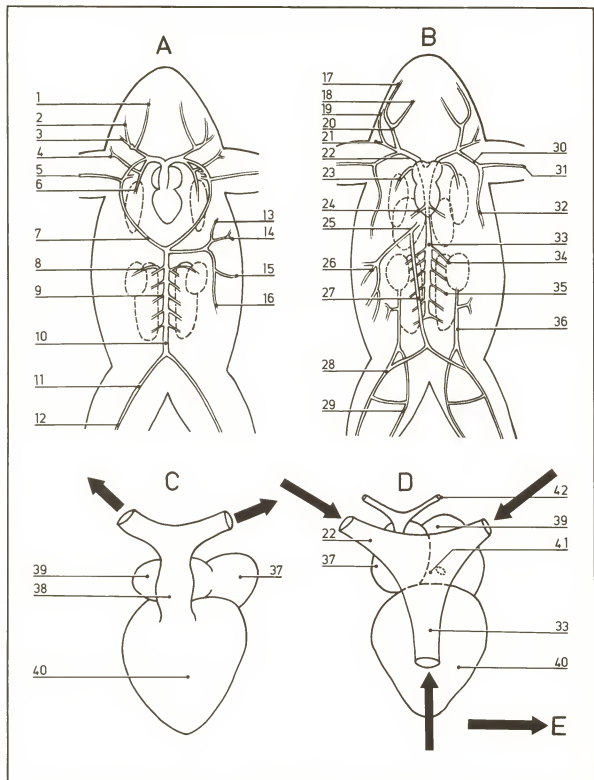
contracted
D Alary muscles relaxed
E Direction of hemolymph flow

1 Aorta
2 Gut
3 Dorsal diaphragm
4 Heart

5 Ostium
6 Ventral diaphragm
7 Pericardial hemocoel
8 Perivisceral hemocoel
9 Sternal hemocoel
10 Alary muscles
11 Ostium open
12 Valve closed
13 Ostium closed
14 Valve open

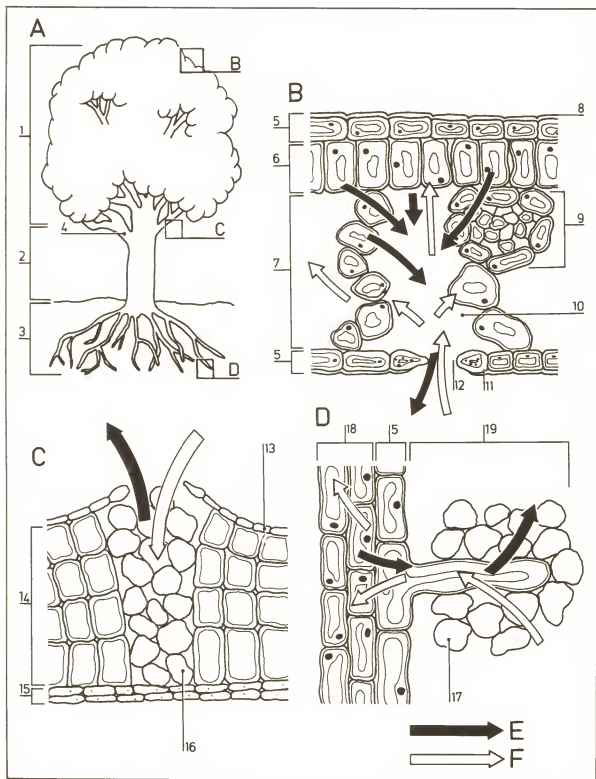
Transport: frog

04.021



Respiration: plants

04.022



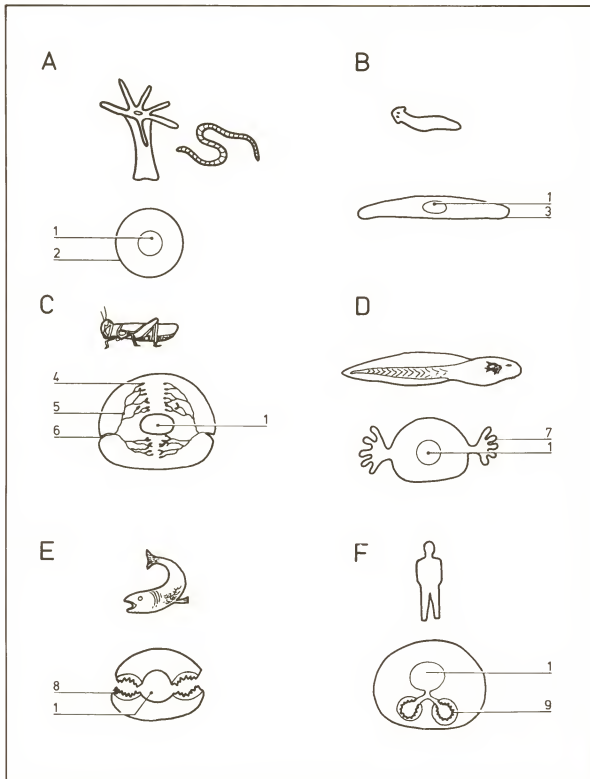
- A Generalized tree
B Leaf – transverse section
C Lenticel – longitudinal section
D Root – longitudinal section
E Oxygen
F Carbon dioxide

- 1 Canopy (foliage)
2 Trunk
3 Roots
4 Branch
5 Epidermis
6 Palisade mesophyll
7 Spongy mesophyll
8 Cuticle
9 Vein

- 10 Air space
11 Guard cell
12 Stoma
13 Remains of epidermis
14 Cork
15 Cork cambium
16 Loose cork cells
17 Soil particles
18 Parenchyma
19 Root hair

Respiration: respiratory surfaces in animals

04.023



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Surfaces for gaseous exchange in a range of animals

A Entire body surface (*Hydra*, earthworm)

B Flattened body (flatworm)

C Tracheal system (grasshopper)

D External gills (young tadpole)

E Internal gills (fish)

F Lungs (human)

1 Gut

2 Body surface

3 Flattened body surface

4 Tracheole

5 Trachea

6 Spiracle

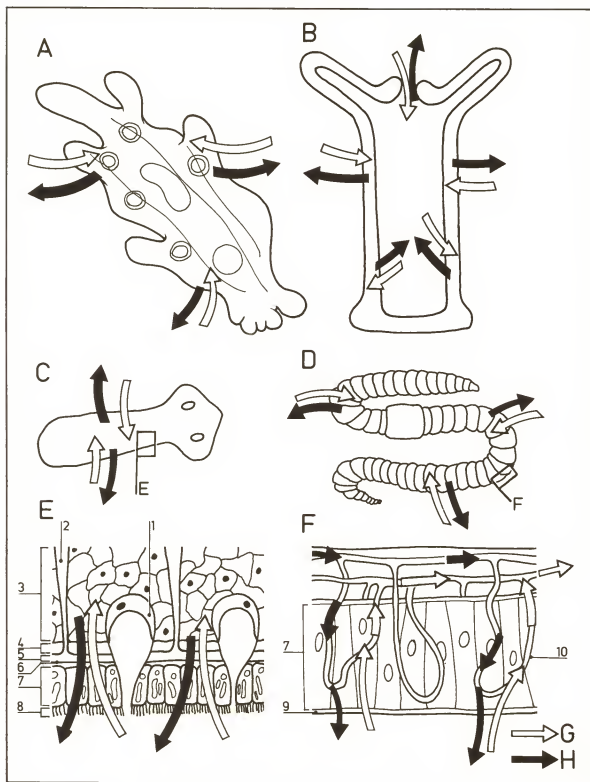
7 External gill

8 Internal gill

9 Lung

Respiration: gas exchange across body surface

04.024

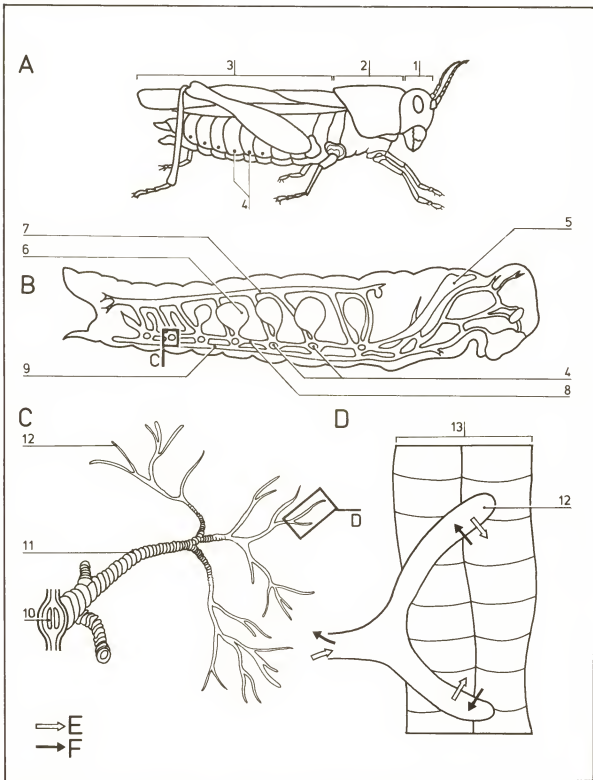


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- | | |
|--|------------------------|
| A <i>Amoeba</i> | 1 Gland cell |
| B <i>Hydra</i> | 2 Dorso-ventral muscle |
| C Flatworm | 3 Parenchyma |
| D Earthworm | 4 Longitudinal muscle |
| E Flatworm body wall - vertical section | 5 Circular muscle |
| F Earthworm body wall - vertical section | 6 Basement membrane |
| | 7 Epidermis |
| | 8 Cilia |
| G Oxygen | 9 Cuticle |
| H Carbon dioxide | 10 Capillary |

Respiration: grasshopper

04.025



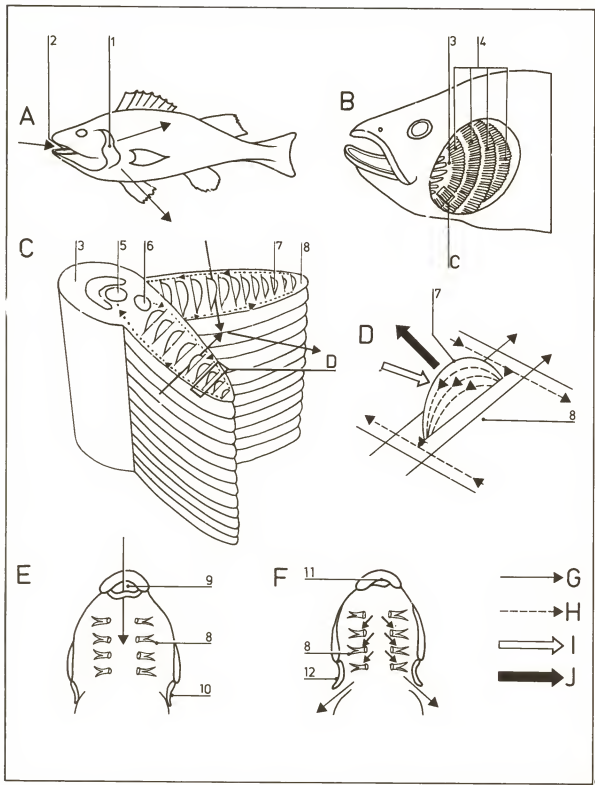
A External view
B Longitudinal section to show tracheal system
C Detail of trachea
D Detail of tracheole
E Oxygen
F Carbon dioxide

1 Head
2 Thorax
3 Abdomen
4 Spiracles
5 Thoracic air sac
6 Abdominal air sacs
7 Dorsal tracheal trunk
8 Lateral tracheal trunk
9 Ventral tracheal trunk

10 Spiracle with valve
11 Trachea
12 Tracheole
13 Muscle fibers

Respiration: fish

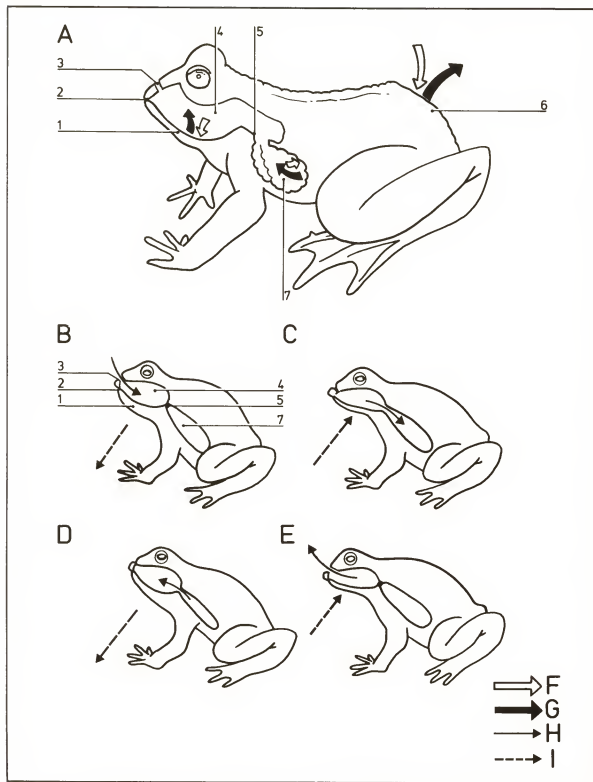
04.026



- | | | |
|----------------------------|-------------------|---------------------|
| A External view | H Flow of blood | 6 Afferent vessel |
| B Head (operculum removed) | I Oxygen | 7 Gill plate |
| C Gill | J Carbon dioxide | 8 Gill filament |
| D Detail of gill filament | | 9 Mouth open |
| E & F Ventilation | 1 Operculum | 10 Operculum closed |
| E Intake of water | 2 Mouth | 11 Mouth closed |
| F Expulsion of water | 3 Gill arch | 12 Operculum open |
| G Flow of water | 4 Gill filaments | |
| | 5 Efferent vessel | |

Respiration: frog

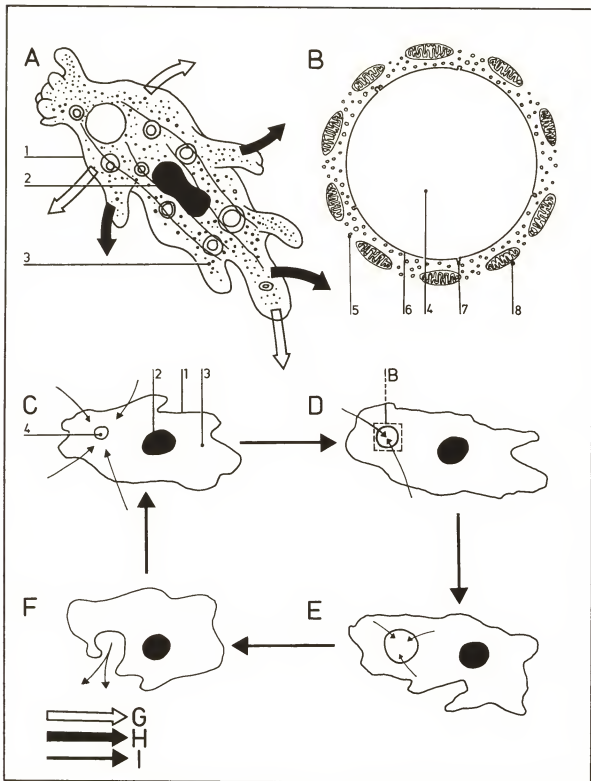
04.027



- A Respiratory surfaces
B-E Ventilation of lungs
B&C Inhalation
D&E Exhalation
F Oxygen
G Carbon dioxide
H Movement of air
I Movement of floor of buccal cavity
- 1 Floor of buccal cavity
2 Mouth
3 Nostril
4 Bucco-pharynx
5 Glottis
6 Skin
7 Lung

Excretion and osmoregulation: Protista

04.028



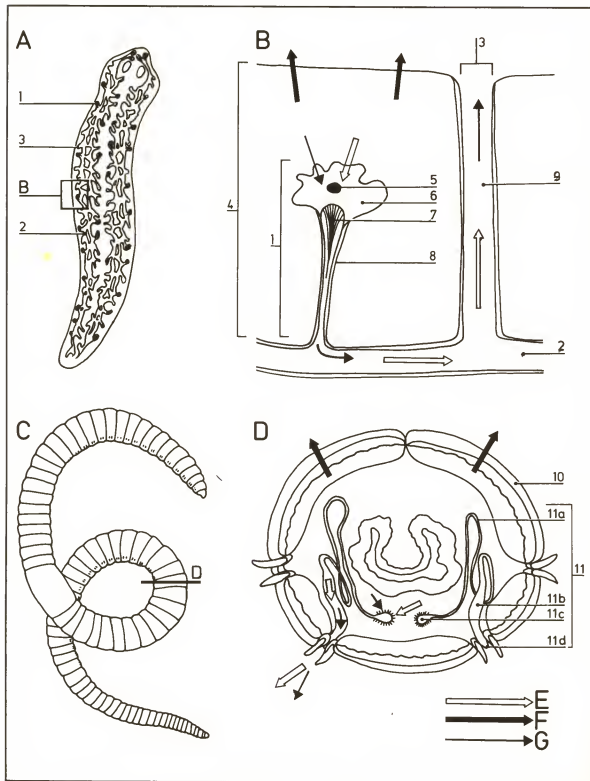
Excretion and osmoregulation in *Amoeba*

- A Excretion
B-F Osmoregulation
C Contractile vacuole (electron microscope)
C-F Contractile vacuole formation and discharge
G Nitrogenous waste
H Carbon dioxide
I Water

- 1 Cell membrane
2 Nucleus
3 Cytoplasm
4 Contractile vacuole
5 Vesicle containing water
6 Vacuole membrane
7 Vesicle fusing with vacuole membrane
8 Mitochondrion

Excretion and osmoregulation: flatworm and earthworm

04.029



A Flatworm showing excretory system
B Detail of flame cell and excretory pore
C Earthworm
D Transverse section intestinal region to show excretory system

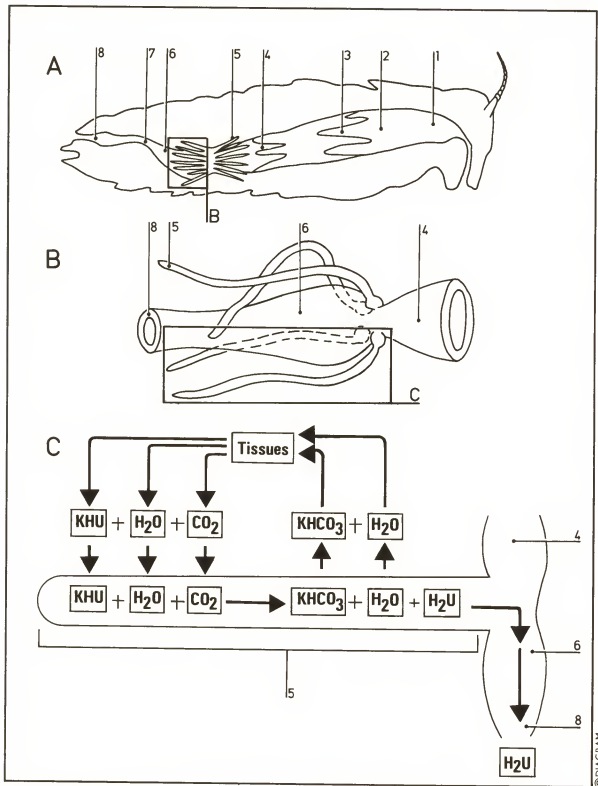
E Nitrogenous waste
F Carbon dioxide
G Water
1 Flame cell
2 Excretory canal
3 Excretory pore
4 Body wall
5 Nucleus

6 Cytoplasm
7 Flagella
8 Nephridial duct
9 Excretory duct
10 Epidermis
11 Nephridium

11a Nephridium tubule
11b Nephridium bladder
11c Excretory duct (ciliated)
11d Nephridiopore

Excretion and osmoregulation: grasshopper

04.030



- A Gut and excretory system
B Relationship between gut and excretory system
C Mechanism of uric acid excretion by malpighian tubule

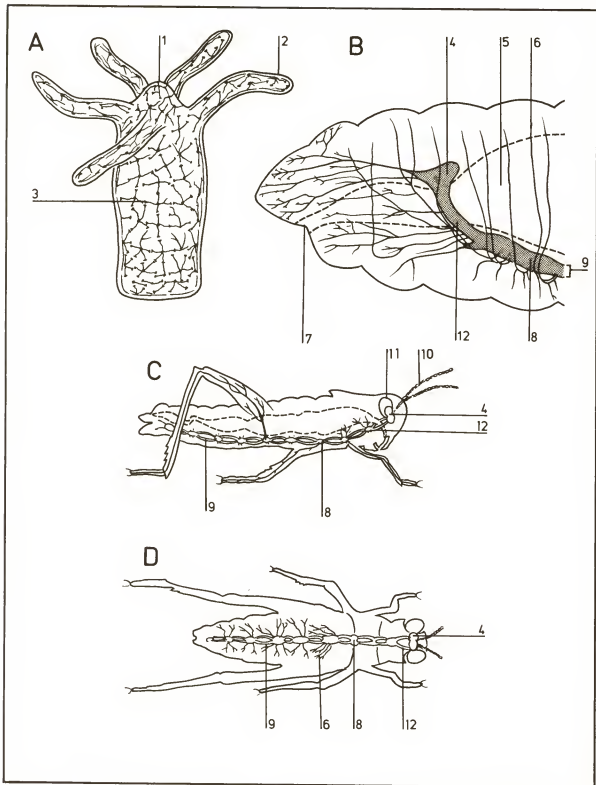
- 5 Malpighian tubules
6 Hindgut
7 Colon
8 Rectum

- 1 Crop
2 Gizzard
3 Cecum
4 Midgut

KHU = potassium urate
 H_2U = uric acid
 KHCO_3 = potassium bicarbonate

Coordination: nervous systems

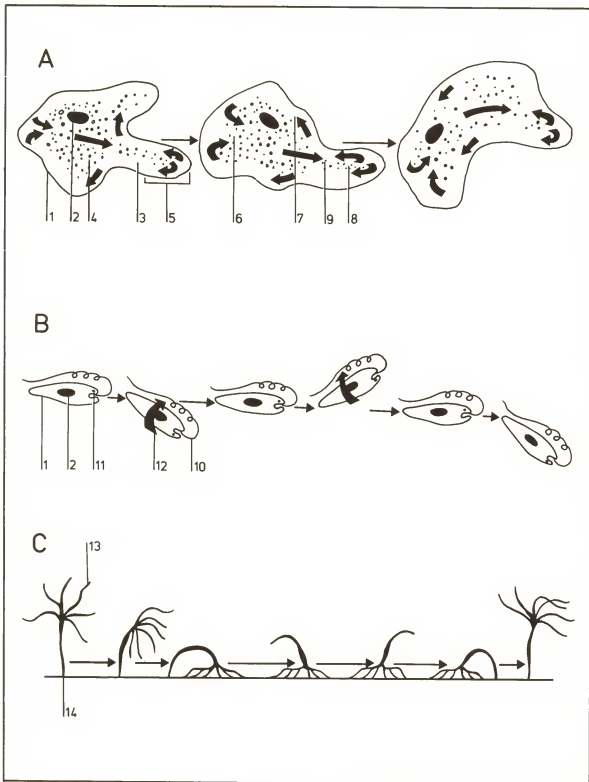
04.031



- A** *Hydra*
B Earthworm
 (longitudinal section –
 anterior end)
C Grasshopper (lateral
 view)
D Grasshopper (dorsal
 view)
- 1 Mouth
 2 Tentacle
 3 Network of nerve cells
 4 Cerebral ganglion
 (brain)
 5 Pharynx
 6 Segmental nerves
 7 Mouth
 8 Ganglion
 9 Ventral nerve cord
 10 Antenna
 11 Compound eye
 12 Nerve collar

Locomotion: Protista and Coelenterata

04.032



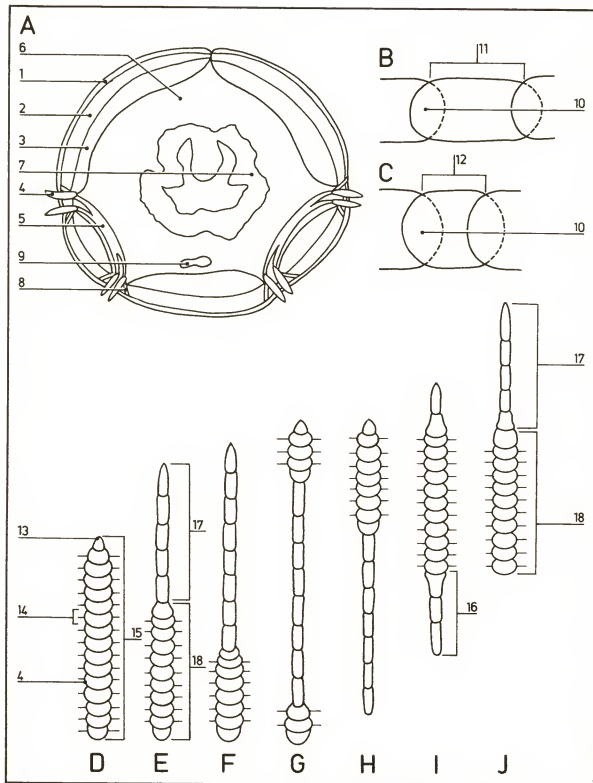
©DIAGRAM

- A** *Amoeba*
B *Euglena*
C *Hydra*
- 1 Cell membrane
 - 2 Nucleus
 - 3 Ectoplasm
 - 4 Endoplasm
 - 5 Pseudopodium

- 6 Gel → sol transformation
- 7 Plasmagel movement
- 8 Sol → gel transformation
- 9 Plasmagel movement
- 10 Flagellum (helical beat)
- 11 Eye spot
- 12 Direction of spin
- 13 Tentacle
- 14 Basal disc

Locomotion: earthworm

04.033



- A** Transverse section – intestinal region
B-C Schematic body segment under different conditions of muscle contraction
B Circular muscles contracted, longitudinal muscles relaxed

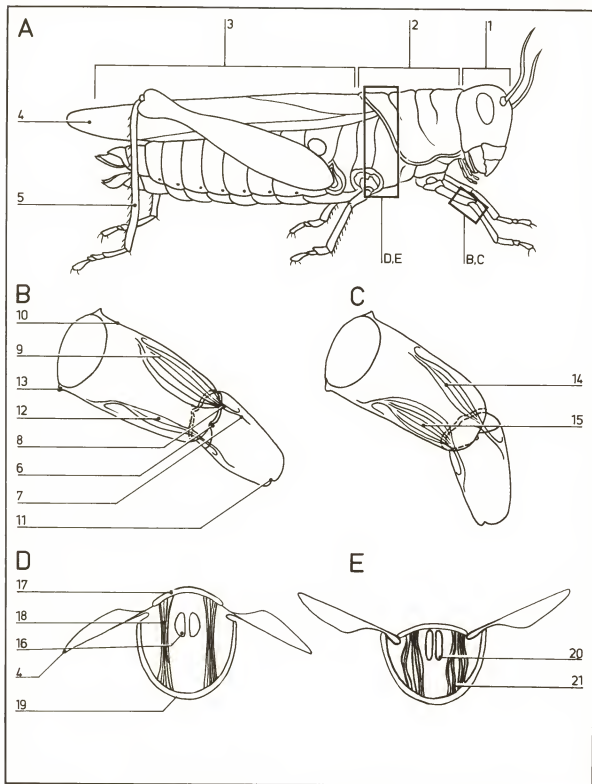
- C** Longitudinal muscles contracted, circular muscles relaxed
D-J Movement
 1 Epidermis
 2 Circular muscle
 3 Longitudinal muscle
 4 Seta

- 5 Seta retractor muscle
 6 Coelom (hydrostatic skeleton)
 7 Intestine
 8 Seta protractor muscle
 9 Nerve cord
 10 Septum
 11 Segment, long and thin

- 12 Segment, short and fat
 13 Anterior end
 14 Segment
 15 Worm at rest
 16 Retracting region
 17 Septum
 18 Stationary region

Locomotion: grasshopper

04.034



- A** Grasshopper – external view
B–C Limb movement (schematic section of leg)
B Extended
C Flexed
D–E Wing movement (transverse section – thorax)

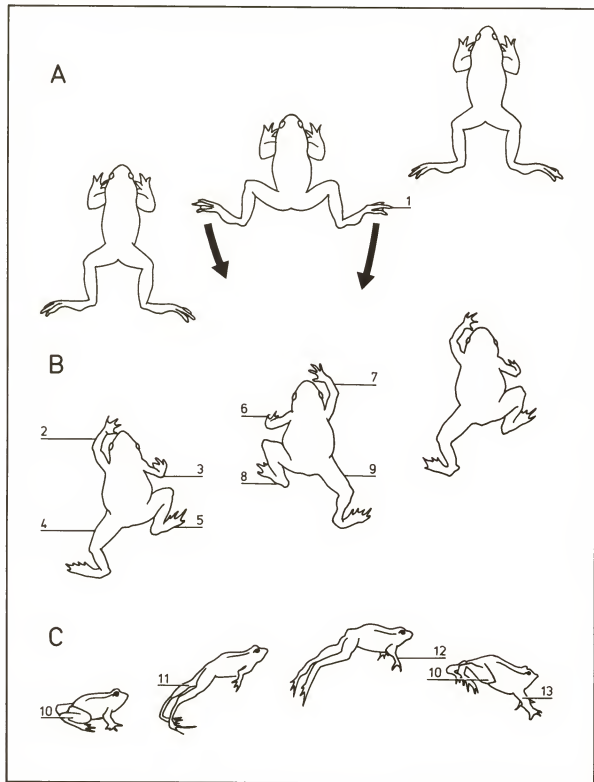
- D** Downstroke
E Upstroke
1 Head
2 Thorax
3 Abdomen
4 Wing
5 Leg
6 Peg and socket joint
7 Muscle attachment
8 Tendon

- 9** Extensor muscle contracted
10 Cuticle (exoskeleton)
11 Socket
12 Flexor muscle relaxed
13 Peg
14 Extensor muscle relaxed
15 Flexor muscle contracted

- 16** Longitudinal muscles contracted
17 Tergum
18 Dorsio-ventral muscles relaxed
19 Sternum
20 Longitudinal muscles relaxed
21 Dorsio-ventral muscles contracted

Locomotion: frog

04.035



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A Swimming
B Walking
C Jumping

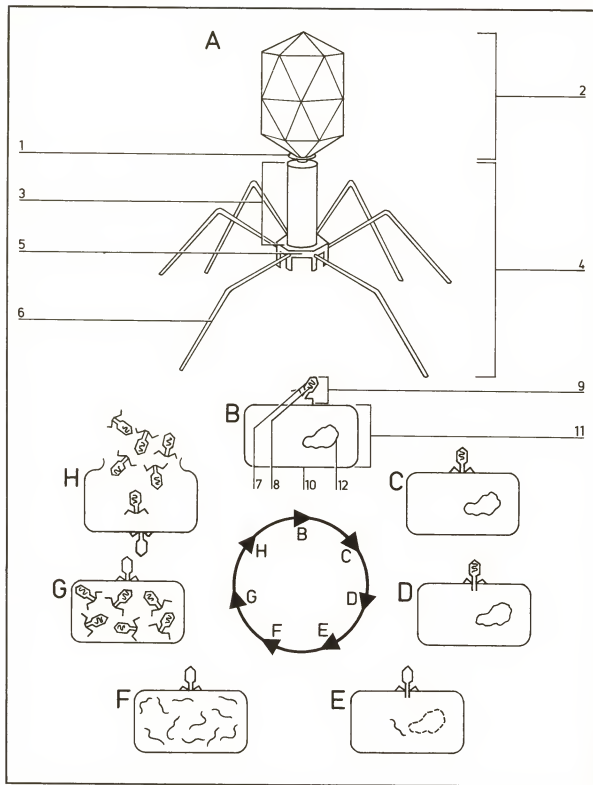
- 1 Webbed foot moves back, pushing against water, thrusting animal forwards
- 2 Left forelimb extends

- 3 Right forelimb retracts
- 4 Left hindlimb extends
- 5 Right hindlimb placed forwards
- 6 Left forelimb retracts
- 7 Right forelimb extends
- 8 Left hindlimb placed

- 9 Right hindlimb extends
- 10 Hindlimbs flexed
- 11 Hindlimbs extended
- 12 Forelimbs extended
- 13 Forelimbs act as shock absorbers on landing

Reproduction: viruses

04.036



- A** Bacteriophage structure
B-H Lytic life cycle
C Attachment
D Penetration
E Viral DNA injected into bacterium; bacterial DNA inactivated

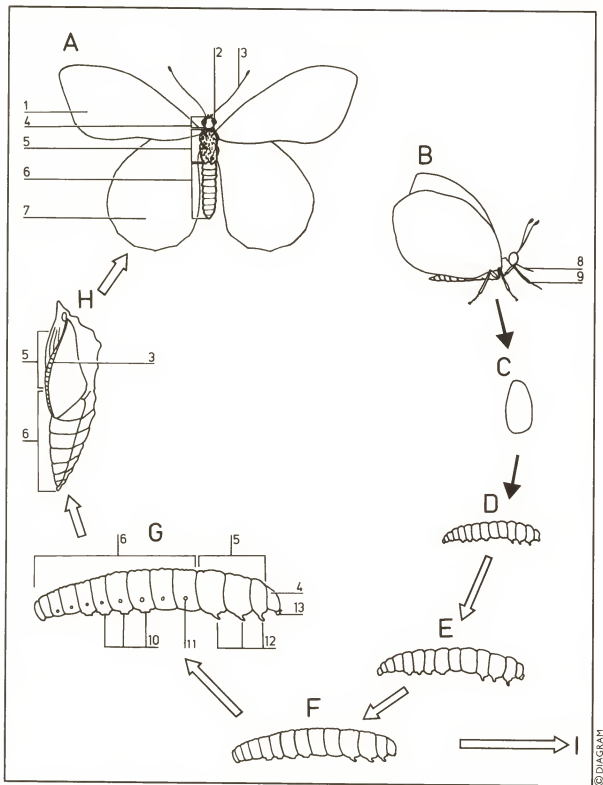
- F** Viral DNA replication
G New protein coats synthesized; new viruses assembled
H Lysis: bacterial cell bursts releasing viruses

- 1** Collar
2 Head
3 Sheath (contractile)
4 Tail
5 Base plate
6 Tail fiber
7 Protein coat
8 Phage DNA
9 Virus (bacteriophage)

- 10** Bacterial cell wall
11 Bacterium (host)
12 Bacterial DNA

Reproduction: butterfly

04.038



Life cycle (complete metamorphosis)
A Adult - dorsal view
B Adult - lateral view
C Egg
D-G Larval stages (caterpillar)
H Pupa
I Molting (ecdysis)

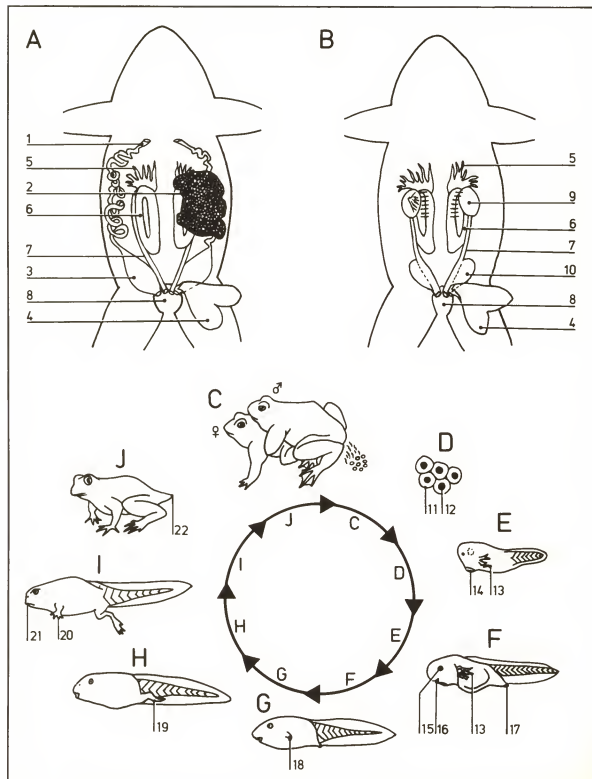
1 Forewing
 2 Compound eye
 3 Antenna
 4 Head
 5 Thorax
 6 Abdomen
 7 Hindwing
 8 Proboscis
 9 Leg

10 Prolegs
 11 Spiracle
 12 True legs
 13 Mandible

© DIAGRAM

Reproduction: frog

04.039

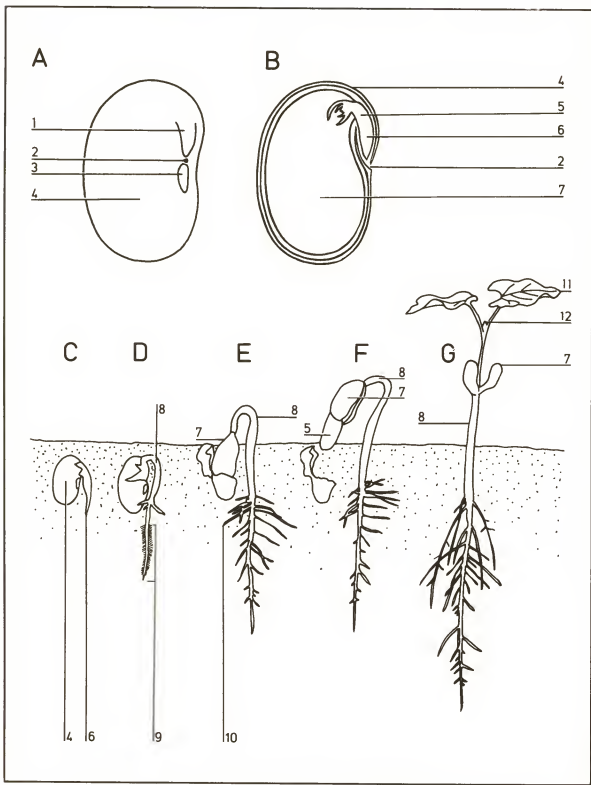


© DIAGRAM

- | | | | |
|----------------------------|--------------------------------------|---------------------|--------------------|
| A, B Urino-genital systems | F Three weeks old | 4 Bladder | 14 Mucous gland |
| A ♀ (right ovary removed) | G One month old | 5 Fat body | 15 Eye |
| B ♂ | H Two months old | 6 Kidney | 16 Mouth |
| C-J Life cycle | I Three months old | 7 Ureter | 17 Anus |
| C Adults mating | J Metamorphosis from tadpole to frog | 8 Cloaca | 18 Spiracle |
| D Eggs | | 9 Testis | 19 Hindlimb |
| E-I Tadpoles | | 10 Seminal vesicle | 20 Forelimb |
| E One day old | | 11 Protective jelly | 21 Mouth widens |
| | | 12 Zygote and yolk | 22 Remains of tail |
| | | 13 External gills | |

Growth and development: plants 1

04.040



Germination of the bean seed (dicotyledon)

A Seed – external view
B Seed – longitudinal section

C–G Germination (epigeal)

C Testa splits; radicle emerges

D Hypocotyl starts to grow

E Hypocotyl grows through soil surface

F Cotyledons emerge from soil

G Hypocotyl straightens; true leaves appear

1 Position of radicle

2 Micropyle

3 Hilum

4 Testa

5 Plumule

6 Radicle

7 Cotyledon (one of two)

8 Hypocotyl

9 Root hairs

10 Lateral root

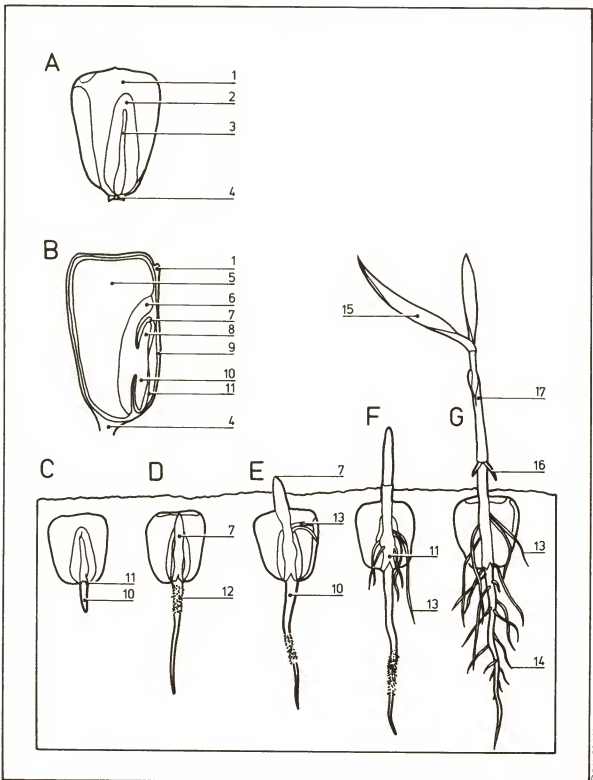
11 True leaf

12 Terminal bud

©DIAGRAM

Growth and development: plants 2

04.041



©DIAGRAM

Germination of the corn seed (monocotyledon)

A Seed - external view

B Seed - longitudinal section

C-F Germination

C Fruit wall splits; radicle appears

D Plumule grows in

coleoptile

E-F Coleoptile appears above soil; adventitious roots develop

G First leaves appear

1 Silk scar
2 Position of

cotyledon

3 Position of embryo
4 Point of attachment
5 Endosperm

6 Cotyledon
7 Coleoptile (plumule sheath)

8 Plumule
9 Pericarp (fused

ovary wall and testa)

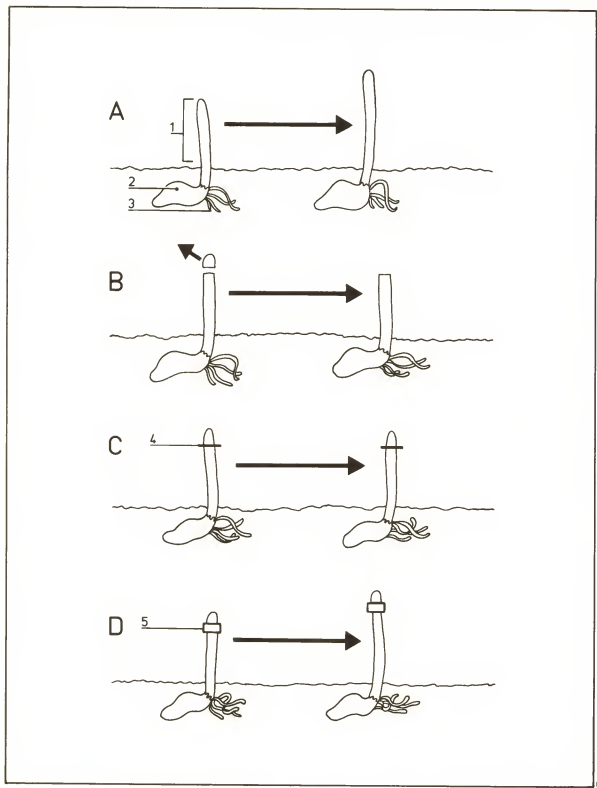
10 Radicle
11 Coleorhiza (radicle sheath)

12 Root hairs
13 Adventitious root

14 Lateral root
15 Leaf
16 Prop root
17 Split coleoptile

Growth and development: plants 3

04.042



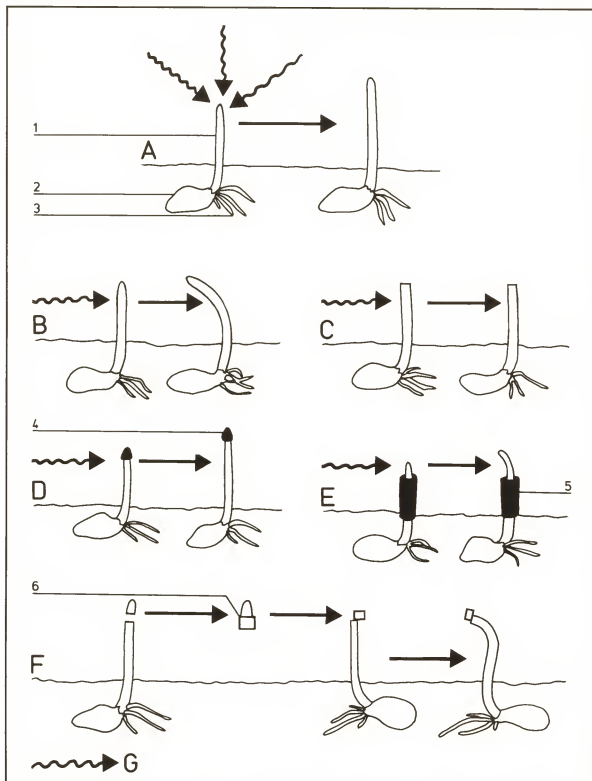
Growth of oat coleoptile under different conditions

- A Untreated coleoptile – growth occurs
- B Coleoptile tip removed – no growth
- C Coleoptile tip removed and replaced but separated from shoot by mica – no growth
- D Coleoptile tip removed and replaced but separated from shoot by agar block – growth occurs

- 1 Coleoptile
- 2 Seed
- 3 Root
- 4 Mica
- 5 Agar

Growth and development: plants 4

04.043



Growth responses to light (phototropism) of oat coleoptile

A Exposed to light from all directions – grows upwards

B-E Exposed to light from one direction

B Grows towards light

(positive phototropism)

C Tip removed – no growth

D Tip covered by light-proof cap – grows upwards

E Zone of elongation covered by

light-proof collar – grows towards light
F Tip removed, placed on agar block. Block replaced on right side of another decapitated coleoptile. Auxin diffuses into zone of

elongation causing growth to the left
G Light

1 Coleoptile

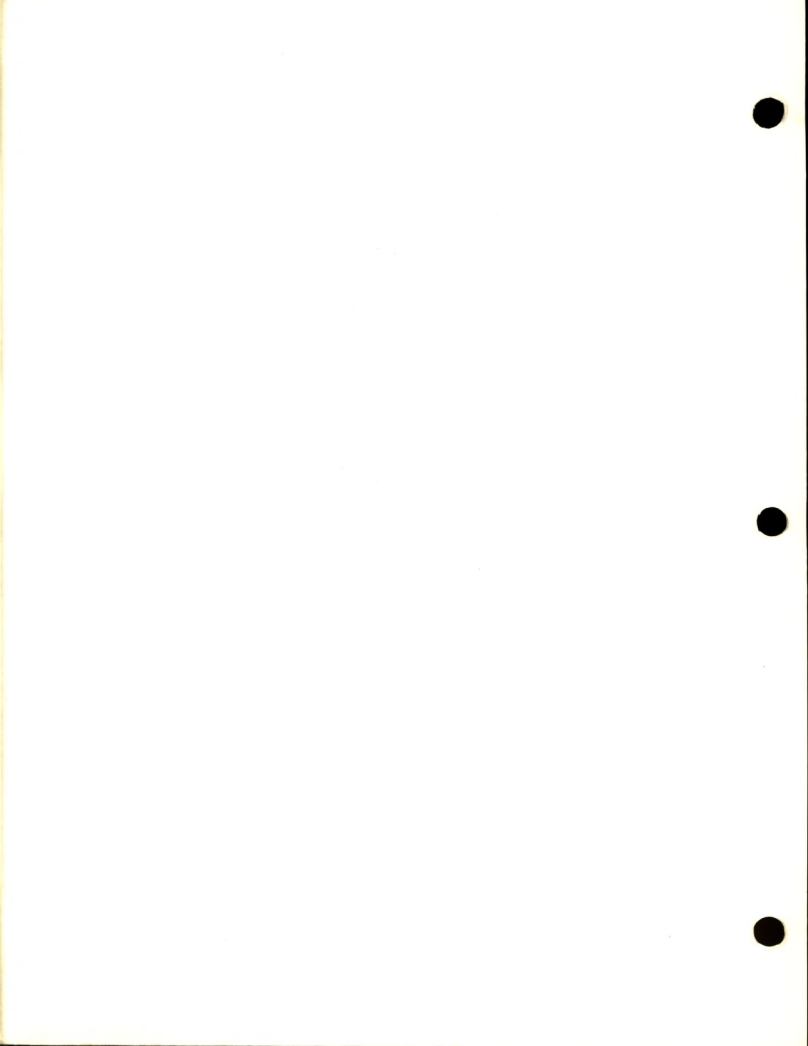
2 Seed

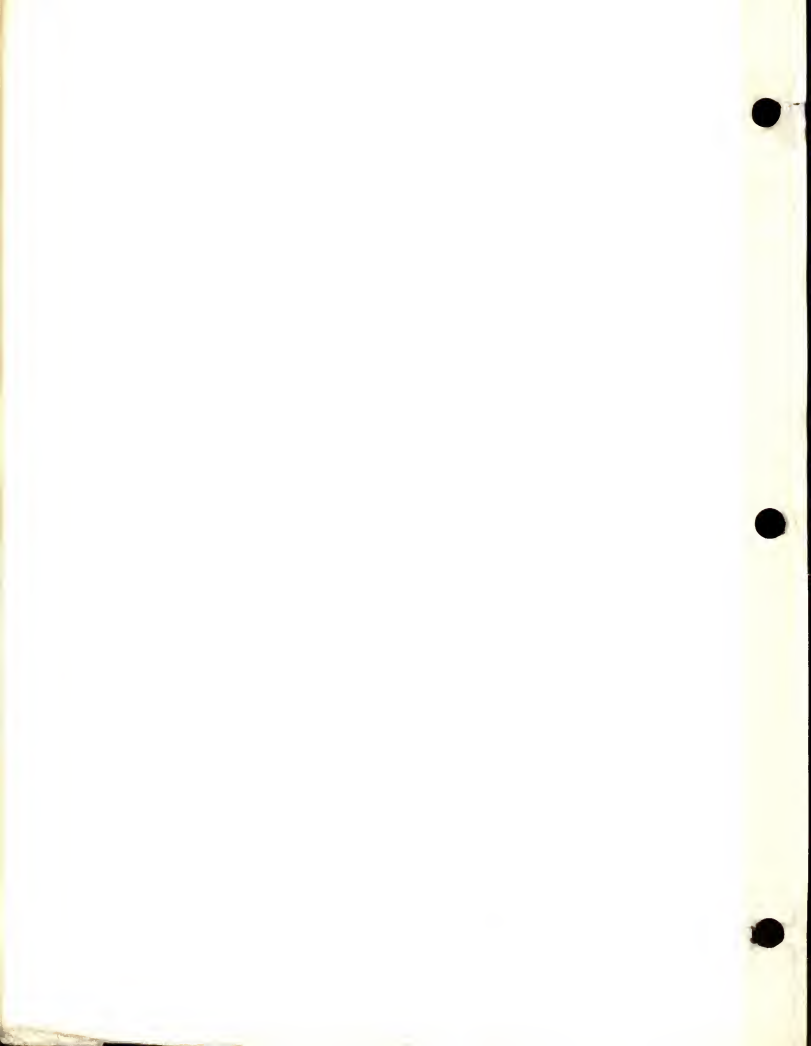
3 Root

4 Light-proof cap

5 Light-proof collar

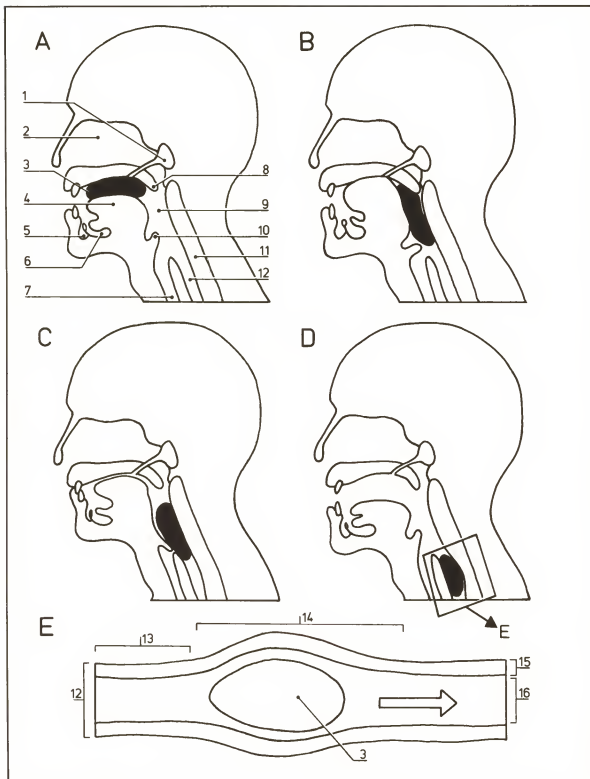
6 Agar block





Nutrition: swallowing and peristalsis

05.003



Vertical section of head and neck to show

A-D Swallowing

A Food pushed upwards and backwards by tongue

B Opening to nasal cavity closed by soft palate

C Food enters esophagus; epiglottis covers entrance to trachea

D Food moved along esophagus by peristalsis

E Esophagus (longitudinal section) to show peristalsis

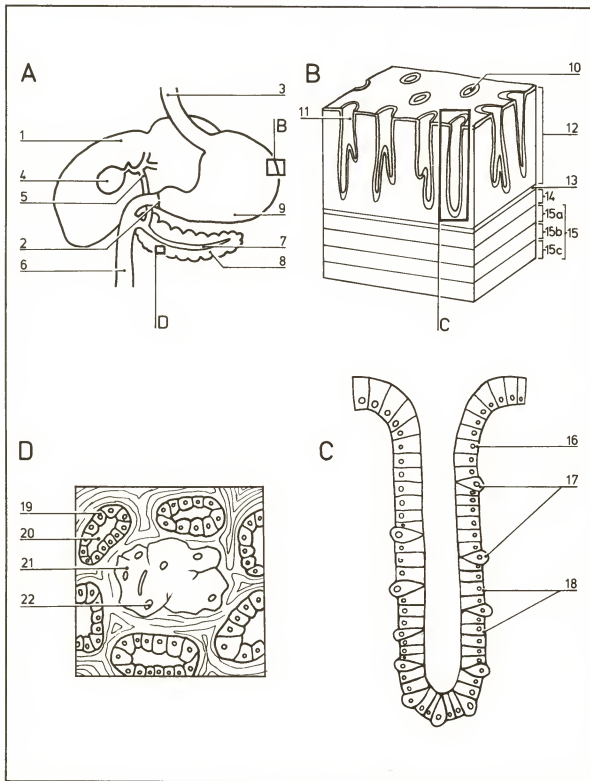
1 Parotid gland
2 Nasal cavity
3 Food (bolus)
4 Tongue
5 Sublingual gland
6 Submaxillary gland
7 Trachea
8 Soft palate
9 Pharynx
10 Epiglottis

11 Vertebral column
12 Esophagus
13 Region of circular muscle contraction
14 Region of circular muscle relaxation
15 Wall of esophagus
16 Lumen of esophagus

© DIAGRAM

Nutrition: liver, stomach and pancreas

05.004



- A** Liver, stomach and pancreas
B Section of stomach wall
C Gastric gland
D Section of pancreas
- 1 Liver
 2 Pyloric sphincter
 3 Esophagus

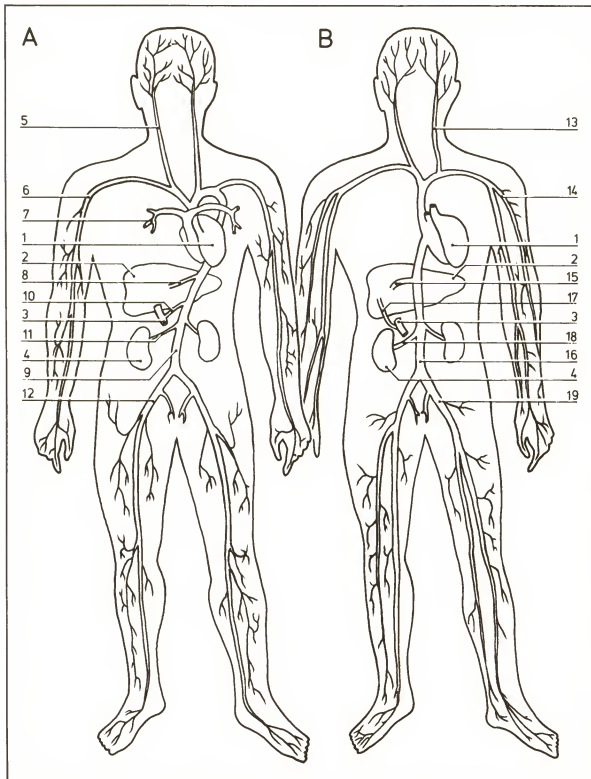
- 4 Gall bladder
 5 Bile duct
 6 Duodenum
 7 Pancreatic duct
 8 Pancreas
 9 Stomach
 10 Opening of gastric gland
 11 Gastric gland
 12 Mucosa

- 13 Thin muscle layer
 14 Submucosa
 15 Smooth muscle layers
 15a Oblique muscle
 15b Circular muscle
 15c Longitudinal muscle
 16 Mucus secreting cells
 17 Oxyntic cells (secrete hydrochloric acid)

- 18 Chief zymogen cells (secrete pepsin)
 19 Zymogen cell (secretes pancreatic enzymes)
 20 Branch of pancreatic duct
 21 Islet of Langerhans (secretes insulin)
 22 Blood capillary

Transport: circulatory system 1

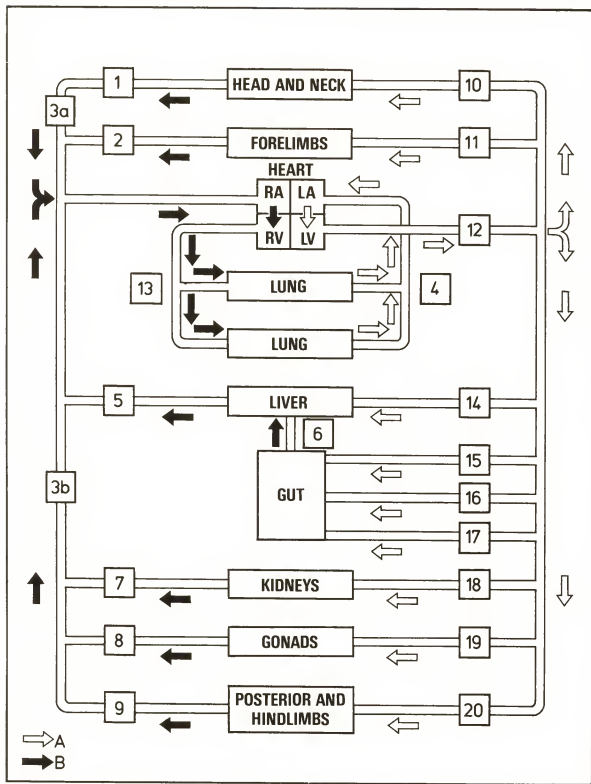
05.007



- | | | |
|----------------------|----------------------|--------------------------|
| A Arteries | 6 Subclavian | 14 Subclavian |
| B Veins | 7 Pulmonary | 15 Hepatic |
| 1 Heart | 8 Hepatic | 16 Vena cava |
| 2 Liver | 9 Aorta | 17 Hepatic portal |
| 3 Gut | 10 Mesenteric | 18 Renal |
| 4 Kidney | 11 Renal | 19 Iliac |
| 5-12 Arteries | 12 Iliac | |
| 5 Carotid | 13-19 Veins | |
| | 13 Jugular | |

Transport: circulatory system 2

05.008



Schematic representation of circulatory system

A. B Direction of blood flow

A Oxygen-rich blood

B Oxygen-poor blood

1-9 Veins

1 Jugular

2 Subclavian

3 Vena cava

3a Superior vena cava

3b Inferior vena cava

4 Pulmonary

5 Hepatic

6 Hepatic portal

7 Renal

8 Genital

9 Iliac

10-20 Arteries

10 Carotid

11 Subclavian

12 Aorta

13 Pulmonary

14 Hepatic

15 Gastric

16 Anterior mesenteric

17 Posterior mesenteric

18 Renal

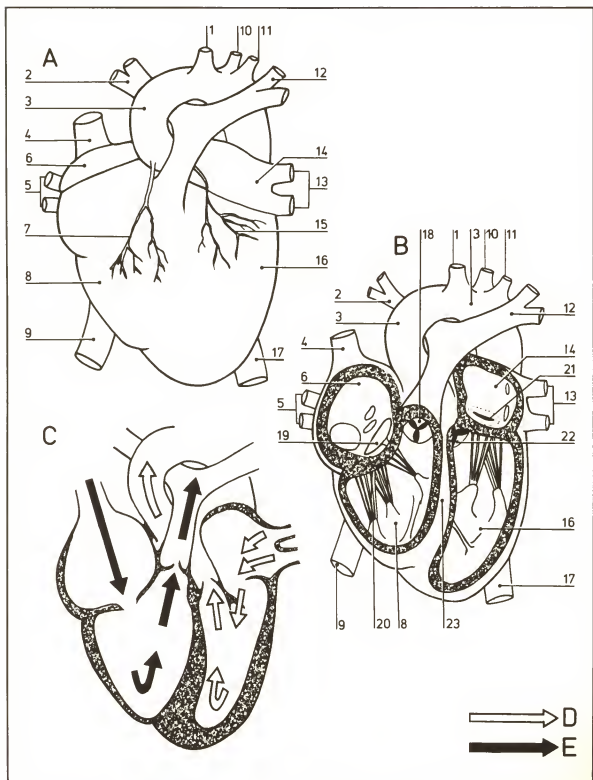
19 Genital

20 Iliac

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Transport: heart structure

05.009



©DIAGRAM

A External view (ventral)
B Section
C Simplified section
showing blood flow
D, E Direction of blood
flow
D Oxygen-rich blood
E Oxygen-poor blood

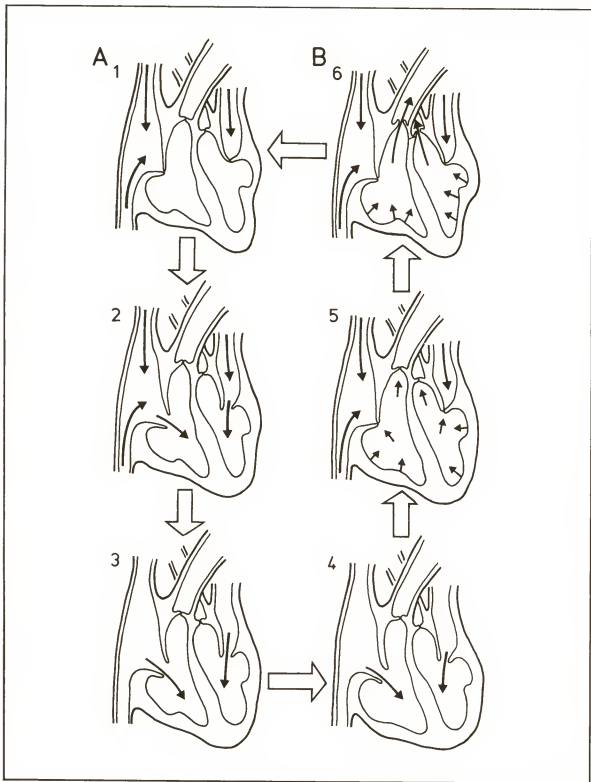
1 Innominate artery
2 Right pulmonary artery
3 Aortic arch
4 Superior vena cava
5 Right pulmonary veins
6 Right atrium
7 Right coronary artery
8 Right ventricle
9 Posterior vena cava

10 Left common carotid
artery
11 Left subclavian artery
12 Left pulmonary artery
13 Left pulmonary veins
14 Left atrium
15 Left coronary artery
16 Left ventricle
17 Aorta

18 Pulmonary valve
19 Tricuspid valve
20 Valve tendon
21 Mistral (bicuspid) valve
22 Aortic valve
23 Interventricular septum

Transport: heart beat

05.010



©DIAGRAM

Sequence showing pumping action of heart

A Diastole (relaxation of heart muscle)

B Systole (contraction of heart muscle)

1 Atria fill – atrioventricular (mitral and tricuspid) valves are closed

2 Atrioventricular valves are pushed open by rising atrial pressure – ventricles start to fill

3 Ventricles continue to fill by suction from relaxed

ventricular walls and atrial contraction

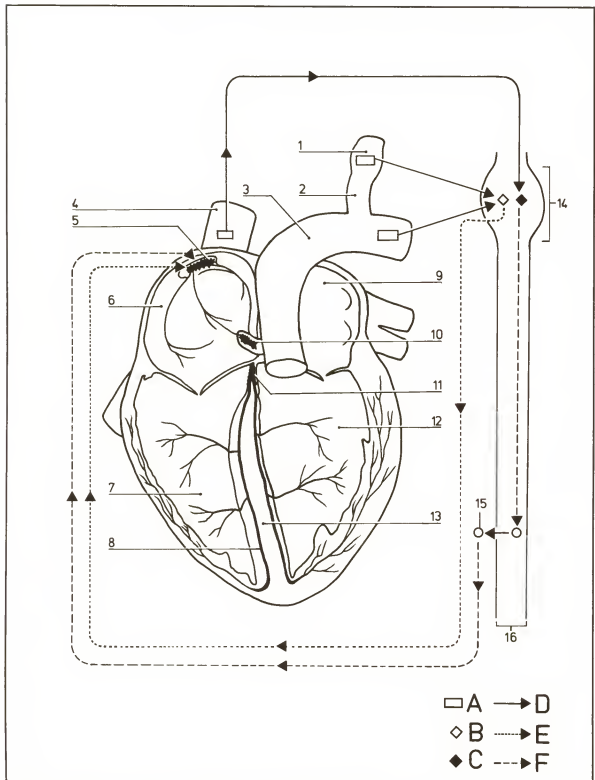
4 Ventricles become full and stretched – atrioventricular valves close

5 Ventricles contract and pressure increases – aortic and pulmonary valves remain closed

6 Ventricles continue to contract – rising pressure pushes open the aortic and pulmonary valves

Transport: regulation of heart beat

05.011



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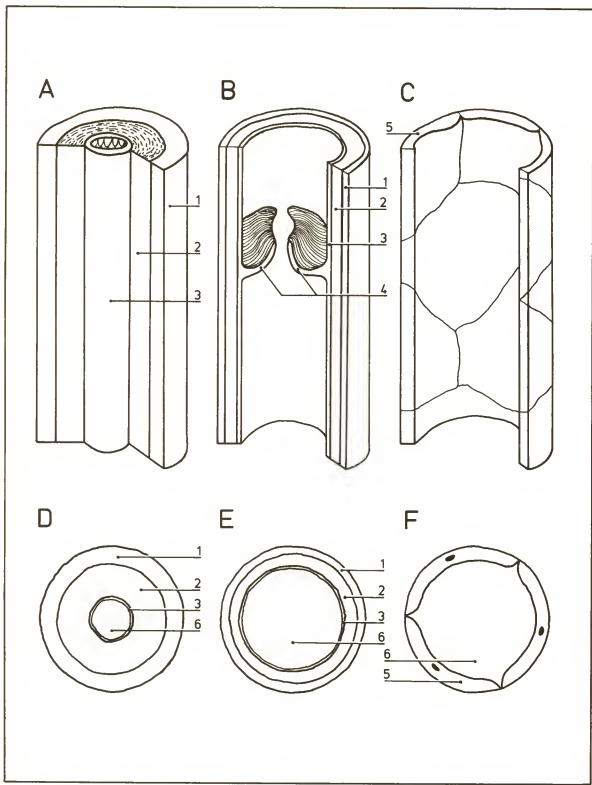
- A Sensory receptor
B Cardio-inhibitor center
C Cardio-accelerator center
D Sensory nerve
E Parasympathetic (inhibitor) nerve
F Sympathetic (accelerator) nerve

- 1 Carotid sinus
2 Carotid artery
3 Aortic arch
4 Superior vena cava
5 Sino-atrial (SA) node (pacemaker)
6 Right atrium
7 Right ventricle
8 Purkinje fibers

- 9 Left atrium
10 Atrioventricular (AV) node
11 Bundle of His
12 Left ventricle
13 Interventricular septum
14 Medulla oblongata
15 Sympathetic ganglion
16 Spinal cord

Transport: blood vessels

05.012

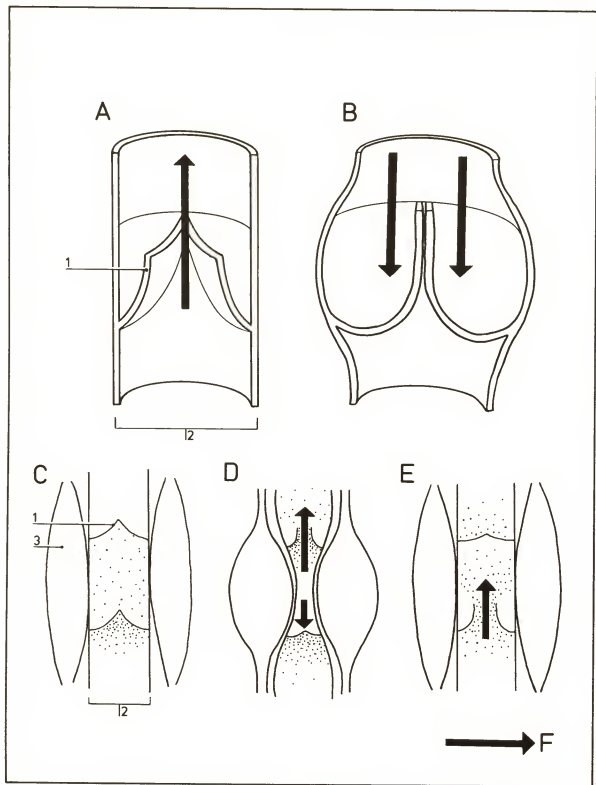


A-C Cut open longitudinally
A Artery
B Vein
C Capillary
D-F Transverse sections
D Artery
E Vein
F Capillary

1 Fibrous (collagen) layer (tunica externa)
2 Smooth muscle and elastic fiber layer (tunica media)
3 Endothelial layer (tunica intima)
4 Valve flaps
5 Endothelial cell
6 Lumen

Transport: valve action

05.013



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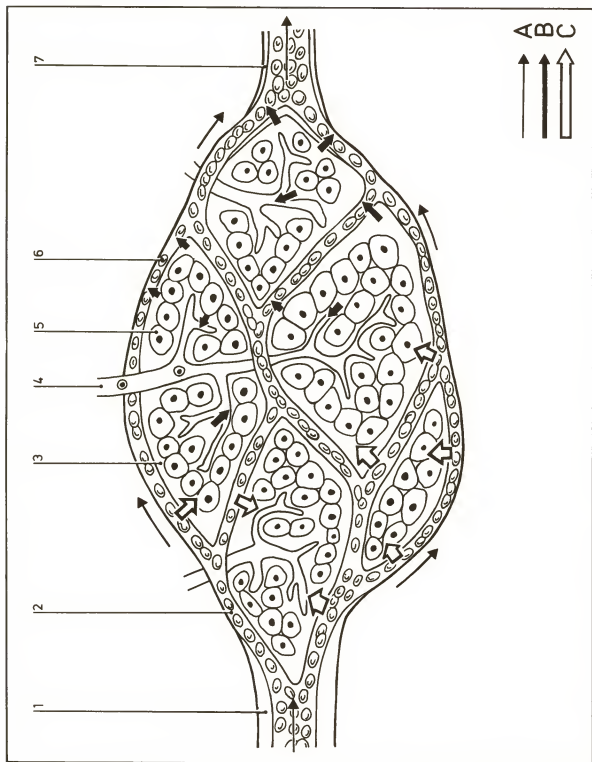
- A, B Action of valve in a vein (longitudinal section)
 A Valve open
 B Valve closed
 C-E Diagram showing how muscle contraction around vein aids flow of blood towards heart
 C Muscles relaxed, valves closed
 D Muscles contract, upper valve opens, lower valve closed

- E Muscles relax, upper valve closed, lower valve opened
 F Direction of blood flow

- 1 Valve
 2 Vein
 3 Muscle

Transport: capillaries and tissues

05.014

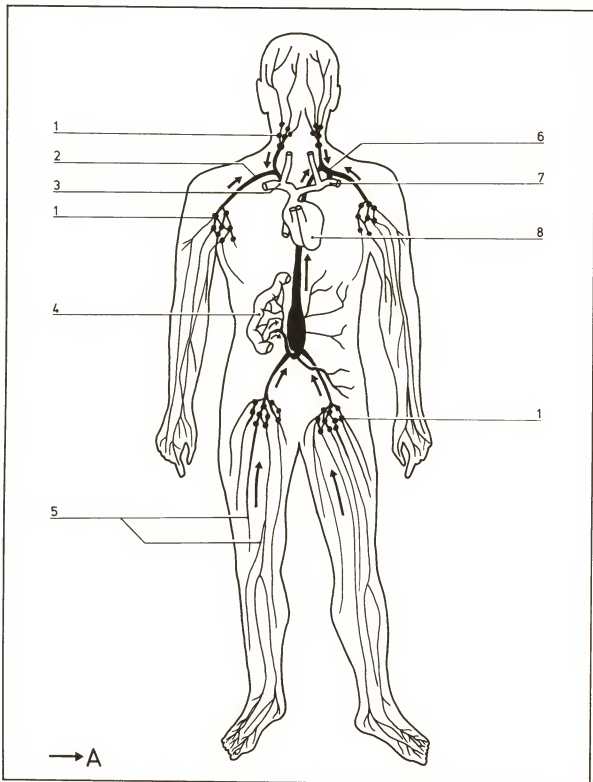


- Relationship between capillaries, lymphatic vessels and tissue cells
- A** Blood flow
 - B** Flow of tissue fluid rich in waste
 - C** Flow of tissue fluid rich in oxygen and food
- 1 Arteriole
 - 2 Capillary
 - 3 Tissue fluid
 - 4 Lymphatic vessel
 - 5 Tissue cell
 - 6 Red blood cell
 - 7 Venule

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Transport: lymphatic system

05.015

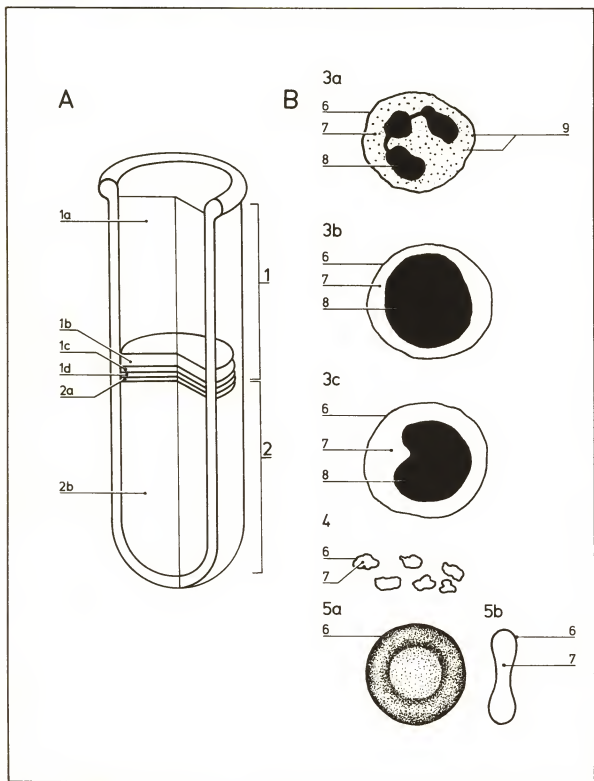


A Direction of lymph flow

- 1 Lymph node
- 2 Right lymphatic duct
- 3 Right subclavian vein
- 4 Ileum
- 5 Lymph vessels
- 6 Left lymphatic duct
- 7 Left subclavian vein
- 8 Heart

Transport: blood composition

05.016



A Blood components separated by centrifugation
B Blood cells

1 Plasma (55%)
1a Water
1b Proteins
1c Organic acids

1d Salts
2 Blood cells (45%)
2a Leukocytes and platelets
2b Red blood cells (erythrocytes)
3 Leukocytes
3a Granulocyte
3b Lymphocyte

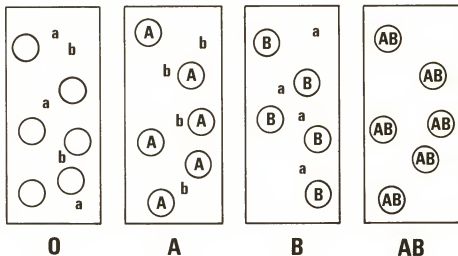
3c Monocyte
4 Platelets
5 Red blood cell (erythrocyte)
5a Surface view
5b Section
6 Cell membrane
7 Cytoplasm
8 Nucleus

9 Granules

Transport: blood types

05.017

A



B

RECIPIENT

DONOR

BLOOD TYPES	O	A	B	AB
O	—	—	—	—
A	+	—	+	—
B	+	+	—	—
AB	+	+	+	—

○ = C

Ⓐ = D

Ⓑ = E

ⒶⒷ = F

a = G

b = H

⊕ = I

— = J

A Diagram to show antibody/antigen composition of different blood types

B Table showing reactions that occur when different blood groups are mixed

O is universal donor

AB is universal recipient

Agglutination occurs if the recipient's blood contains antibodies to the donor's antigens

C Red blood cell with no antigens

D Red blood cell with A antigen

E Red blood cell with B antigen

F Red blood cell with A and B antigens

G Anti-A antibody in plasma

H Anti-B antibody in plasma

I Agglutination occurs

J Agglutination does not occur

Transport: rhesus antigen

05.018

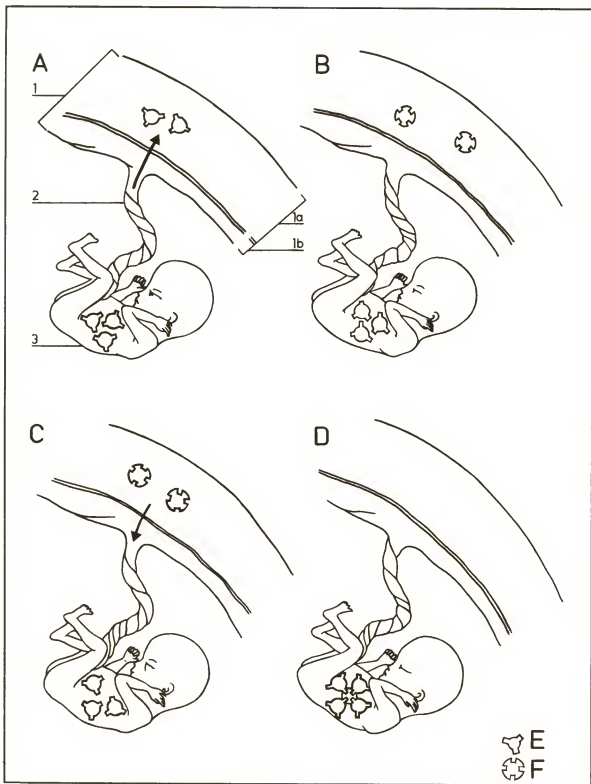


Diagram to show sequence of events leading to clumping of red blood cells in a rhesus positive (Rh+) fetus in a rhesus negative (Rh-) mother during the second pregnancy.

A, B First pregnancy

A Fetal red blood cells

pass into mother's blood stream by damage to the placenta

B Anti-Rh+ antibodies appear in mother's blood

C, D Second pregnancy

C Anti-Rh+ antibodies

pass from mother's blood stream to fetal blood stream

D Reaction of Rh+ antigen on fetal red blood cells and Rh+ antibody causes clumping of fetal red blood cells

E Fetal red blood cell with Rh+ antigen

F Rh+ antibody

1 Placenta

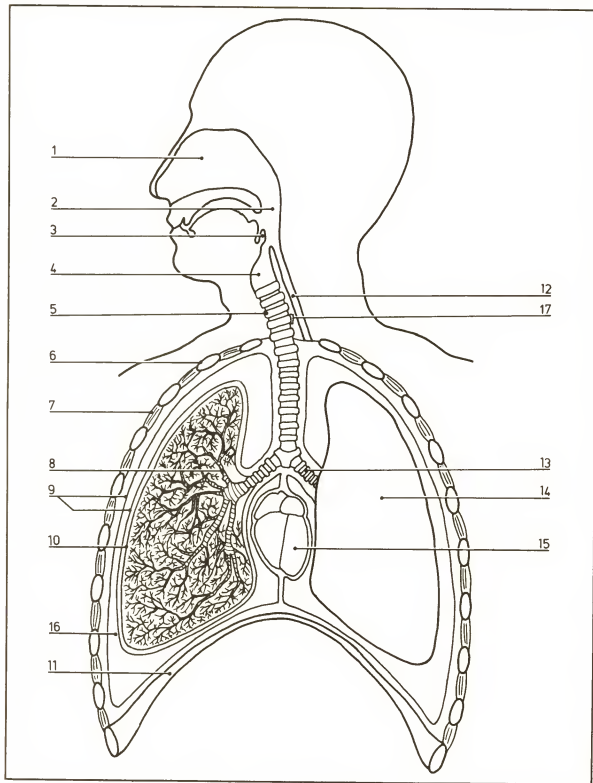
1a Mother's blood stream

2 Fetal blood stream

3 Fetus

Respiration: respiratory system

05.019



Section of head and thorax
to show respiratory
system.

Left lung (surface view)
Right lung (section)

- 1 Nasal cavity
- 2 Pharynx
- 3 Epiglottis

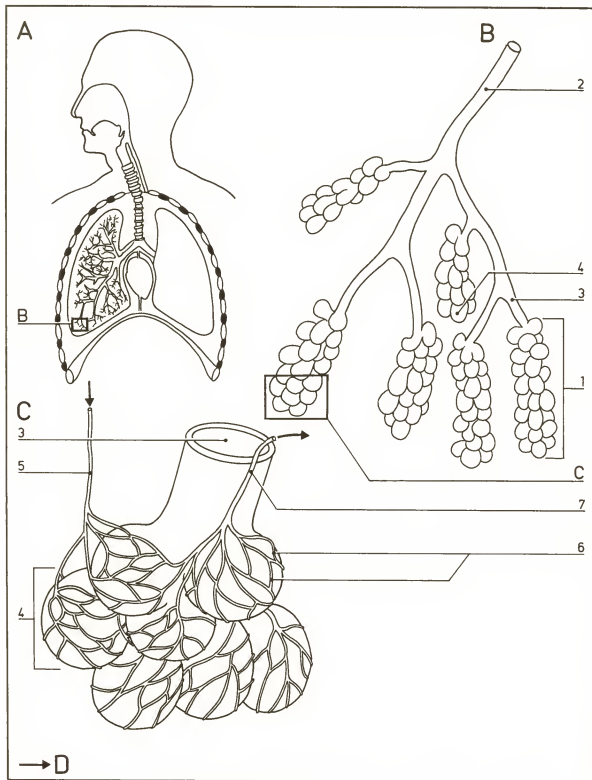
- 4 Larynx
- 5 Trachea
- 6 Rib
- 7 Intercostal muscle
- 8 Bronchiole
- 9 Pleural membranes
- 10 Right lung
- 11 Diaphragm
- 12 Esophagus

- 13 Bronchus
- 14 Left lung
- 15 Heart
- 16 Pleural cavity
- 17 Cartilage

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Respiration: lung structure

05.020



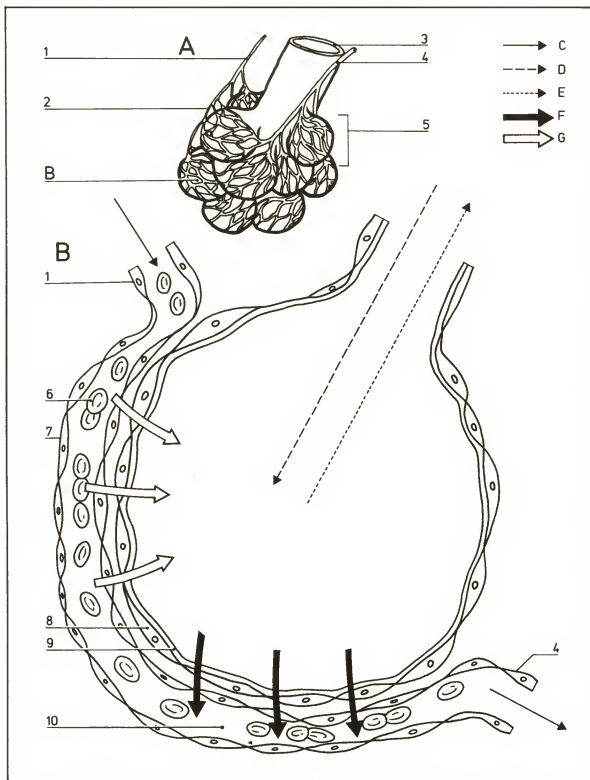
- A Respiratory system
- B Bronchiole and air sacs
- C Alveoli
- D Direction of blood flow
- 5 Branch of pulmonary artery
- 6 Capillary network
- 7 Branch of pulmonary vein

- 1 Air sac
- 2 Bronchiole
- 3 Respiratory bronchiole
- 4 Alveolus

©DIAGRAM

Respiration: gas exchange 1

05.021



©DIAGRAM

Gas exchange in the alveolus

- A Alveoli
- B Section of alveolus
- C Blood flow
- D Inhaled air (rich in oxygen)
- E Exhaled air (poor in oxygen)

F Diffusion of oxygen into blood

G Diffusion of carbon dioxide from blood

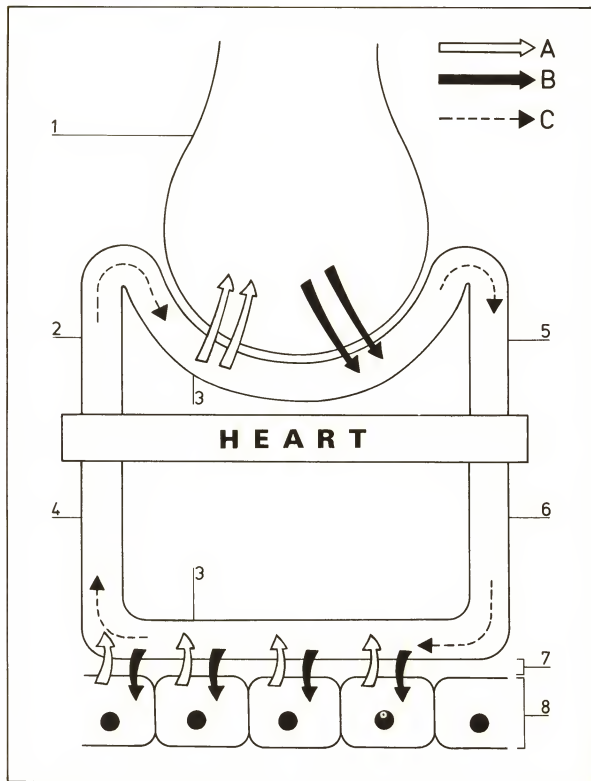
- 1 Branch of pulmonary artery
- 2 Capillary network
- 3 Respiratory bronchiole

4 Branch of pulmonary vein

- 5 Alveolus
- 6 Red blood cell
- 7 Capillary wall
- 8 Epithelium of alveolus
- 9 Film of moisture
- 10 Blood plasma

Respiration: gas exchange 2

05.022



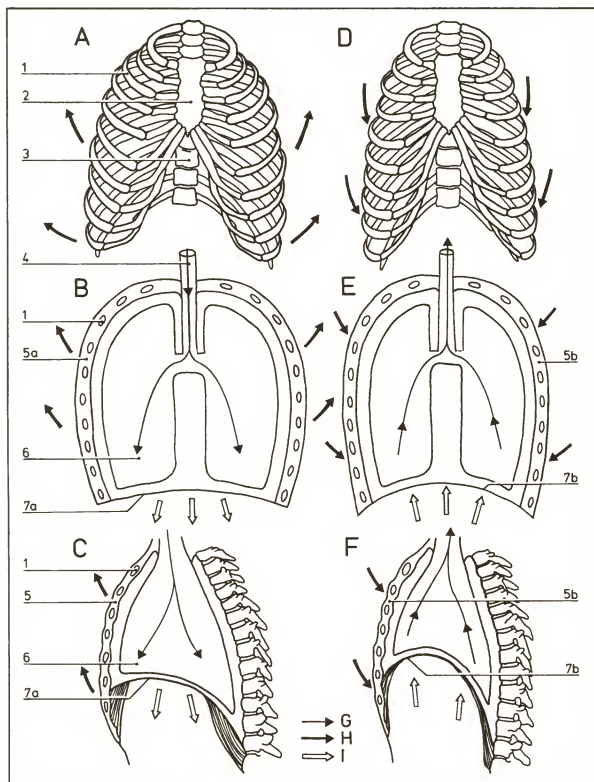
Schematic diagram to show gas exchange between alveolus, blood and tissues

A Diffusion of carbon dioxide
B Diffusion of oxygen
C Direction of blood flow

1 Alveolus
2 Pulmonary artery
3 Capillary
4 Vena cava
5 Pulmonary vein
6 Aorta
7 Tissue fluid
8 Tissue cells

Respiration: breathing

05.023



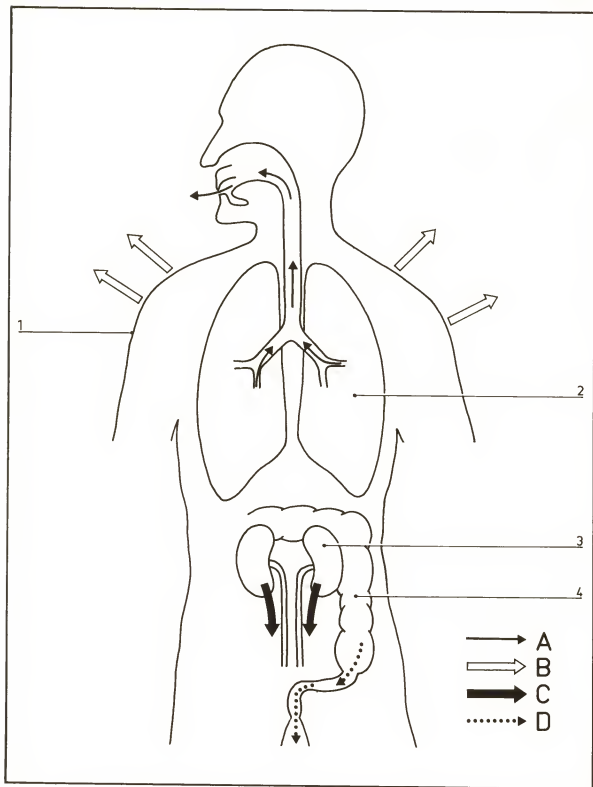
A, B, C Breathing in (inhalation)
D, E, F Breathing out (exhalation)
B, E Thorax section (front view)
C, F Thorax section (side view)
G Movement of air

H Movement of ribs
I Movement of diaphragm
1 Rib
2 Sternum
3 Backbone
4 Trachea
5 Intercostal muscles

5a Contracted
5b Relaxed
6 Lung
7 Diaphragm muscles
7a Contracted
7b Relaxed

Excretion: excretory systems

05.024

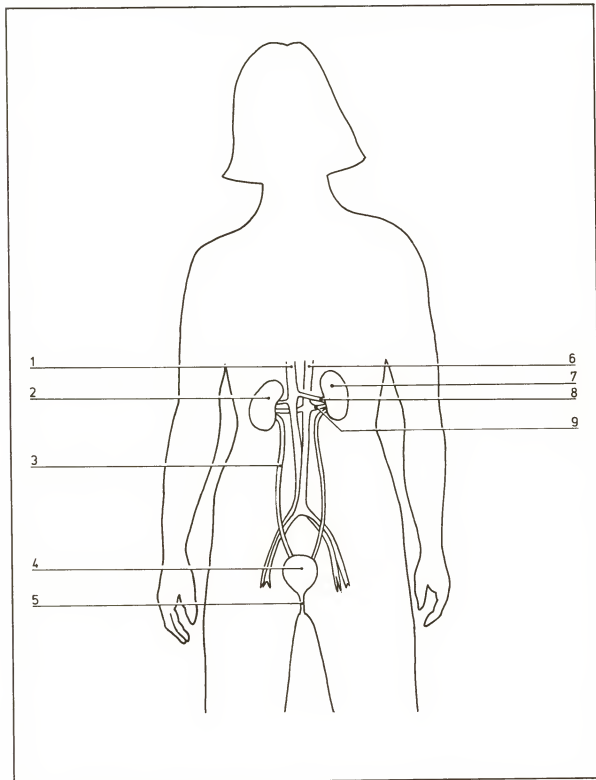


- A Water and carbon dioxide from lungs
B Water, salts and urea from skin
C Urea, water and salts from kidney
D Bile pigments (from liver) via large intestine

- 1 Skin
2 Lung
3 Kidney
4 Intestine

Excretion: urinary system

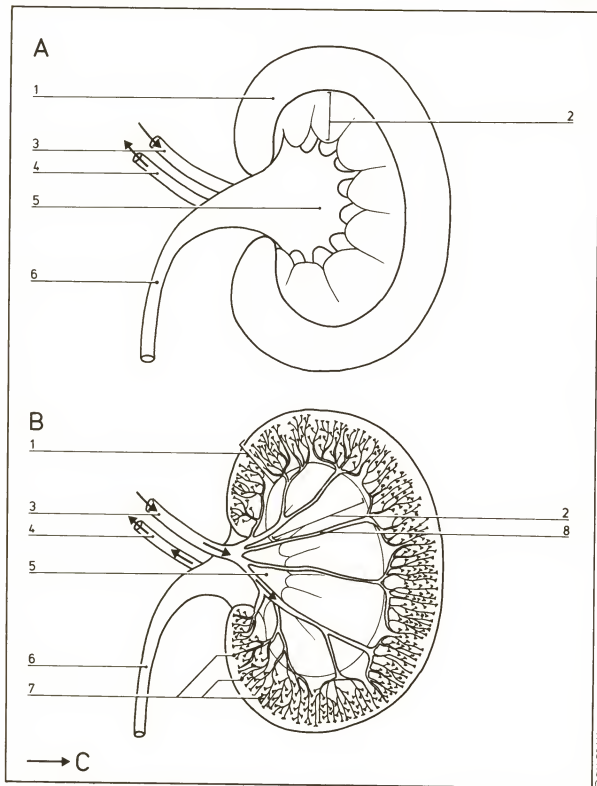
05.025



- 1 Inferior vena cava
- 2 Right kidney
- 3 Ureter
- 4 Bladder
- 5 Urethra
- 6 Aorta
- 7 Left kidney
- 8 Renal vein
- 9 Renal artery

Excretion: kidney structure 1

05.026



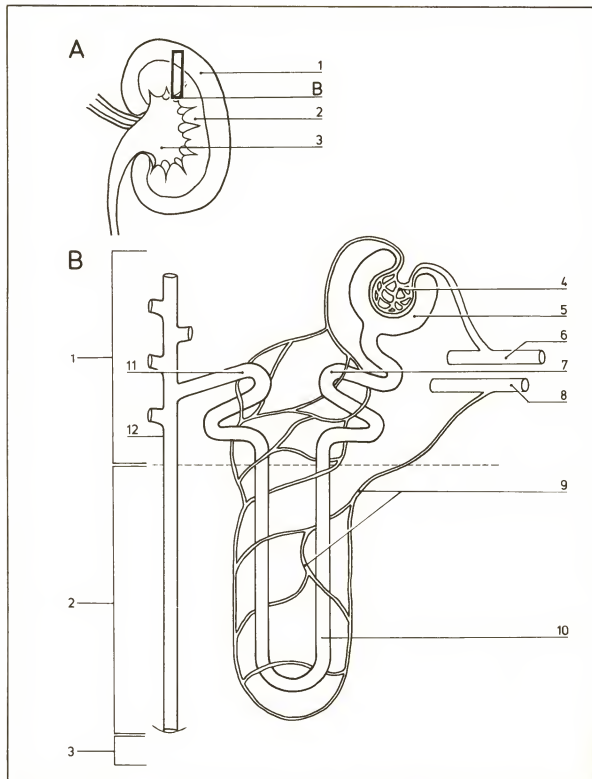
- A Longitudinal section to show sections of kidney
B Longitudinal section to show blood supply to kidney
C Blood flow

- 6 Ureter
7 Glomeruli
8 Branch of renal artery

- 1 Cortex
2 Medulla
3 Renal artery
4 Renal vein
5 Pelvis

Excretion: kidney structure 2

05.027



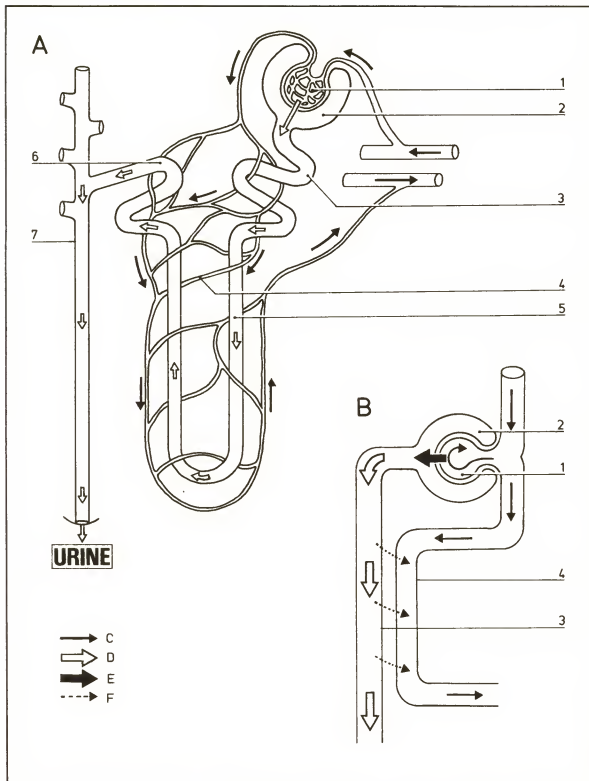
A Kidney – longitudinal section
B Nephron

- 1 Cortex
- 2 Medulla
- 3 Pelvis
- 4 Glomerulus
- 5 Bowman's capsule
- 6 Branch of renal artery

- 7 Proximal convoluted tubule
- 8 Branch of renal vein
- 9 Capillaries
- 10 Loop of Henle
- 11 Distal convoluted tubule
- 12 Collecting duct

Excretion: kidney function

05.028

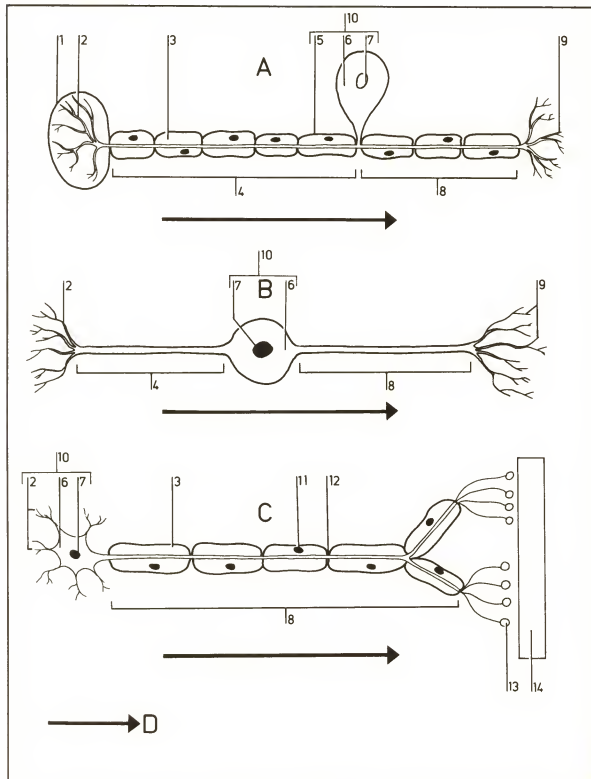


- A Nephron
 B Schematic diagram of first part of nephron
 C Blood flow
 D Filtrate flow
 E Filtration
 F Reabsorption of glucose, amino acids, water, salts

- 1 Glomerulus
 2 Bowman's capsule
 3 Proximal convoluted tubule
 4 Capillary
 5 Loop of Henlé
 6 Distal convoluted tubule
 7 Collecting duct

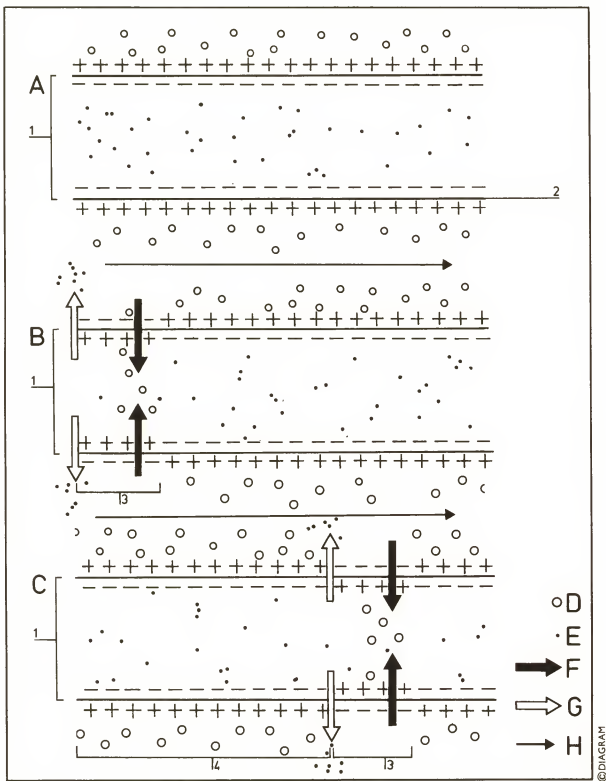
Coordination: neurons

05.031



Coordination: nerve impulse

05.032



A-C Schematic longitudinal section of nerve fiber to show passage of an impulse along the membrane

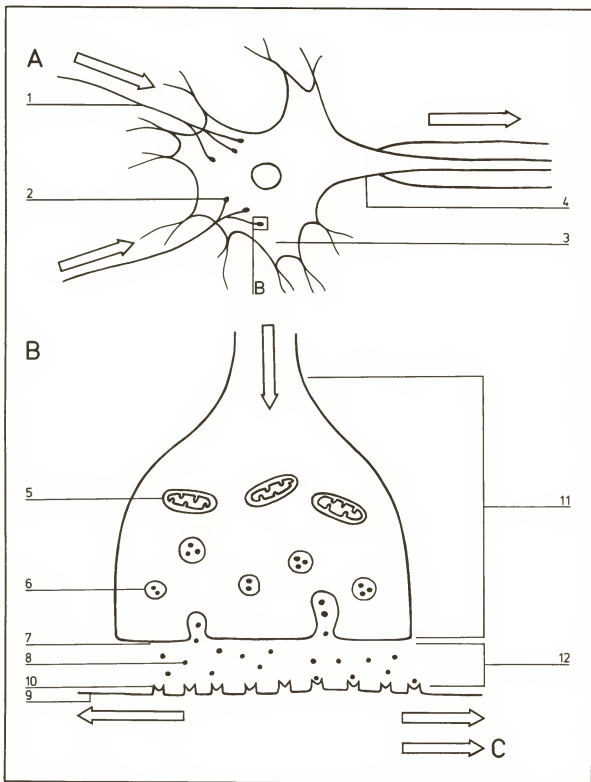
- A Resting state (inside negative, outside positive)
- B Initiation of nerve impulse
- C Propagation of impulse
- D Sodium ion
- E Potassium ion
- F Inflow of sodium ions

G Outflow of potassium ions
H Direction of impulse

- 1 Nerve fiber (neuron)
- 2 Membrane
- 3 Area of depolarization
- 4 Area where charge across membrane has been restored

Coordination: synapse

05.033



A Connections between association and motor neuron

B Schematic representation of transmission across a synapse

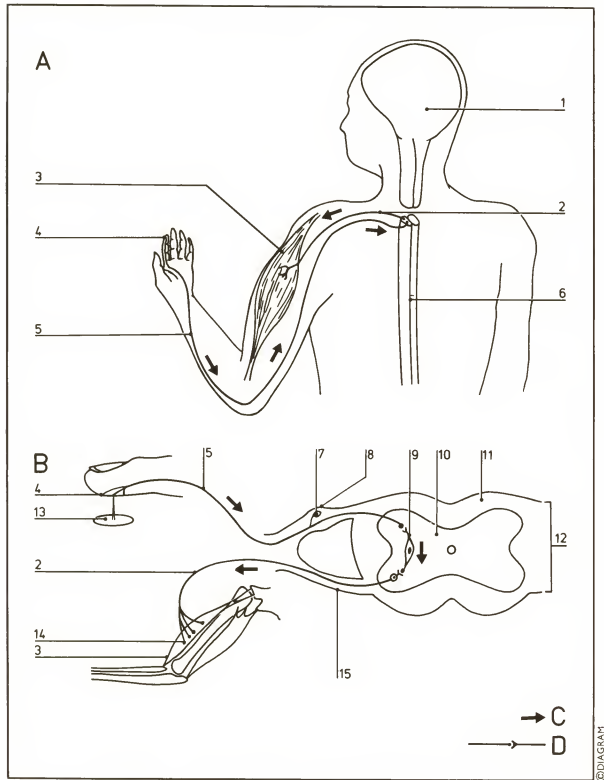
C Direction of impulse

1 Association neuron
2 Synaptic knob
3 Cell body of motor neuron
4 Axon of motor neuron
5 Mitochondrion
6 Synaptic sac
7 Presynaptic membrane
8 Transmitter molecules

9 Postsynaptic membrane
10 Receptor site
11 Synaptic knob
12 Synaptic gap

Coordination: reflex arc

05.034



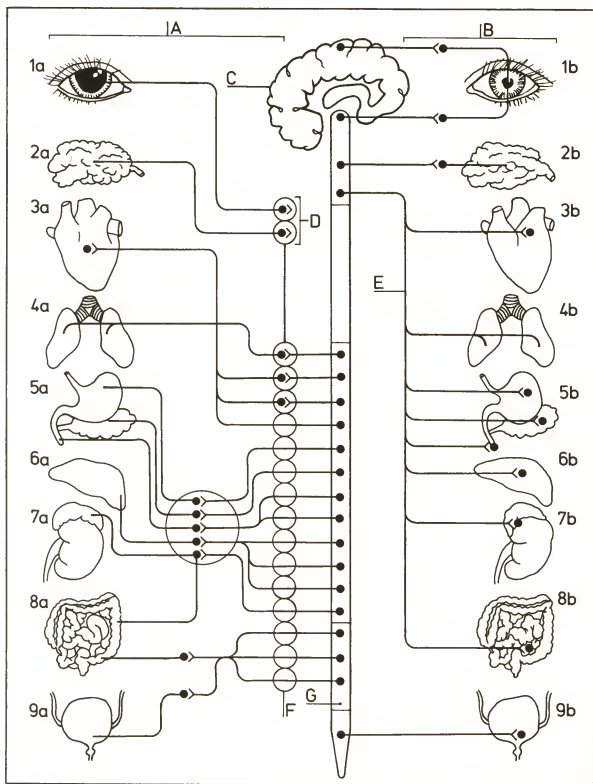
- A** Reflex pathway
B Reflex pathway
showing detail of
receptor, spinal cord
and effector
C Direction of impulse
D Synapse

- 1 Brain
2 Motor neuron
3 Muscle (effector)
4 Sensory receptor in
finger
5 Sensory neuron
6 Spinal cord
7 Cell body
8 Dorsal root ganglion

- 9 Association neuron
10 Gray matter
11 White matter
12 Section of spinal cord
13 Pin (stimulus)
14 Motor end plate
15 Ventral root

Coordination: autonomic nervous system

05.035



A Sympathetic
B Parasympathetic
C Brain
D Cervical ganglia
E Vagus nerve
F Chain ganglia
G Spinal cord

1 Iris
1a Dilates pupil

1b Constricts pupil
2 Salivary gland
2a Inhibits salivation
2b Stimulates salivation
3 Heart
3a Accelerates heart rate
3b Decreases heart rate
4 Bronchi
4a Dilates bronchi
4b Constricts bronchi

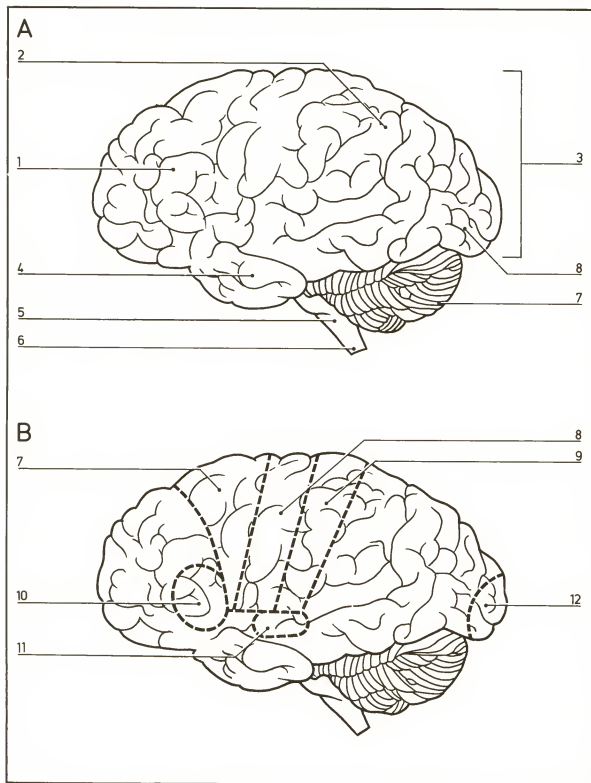
5 Stomach/pancreas
5a Inhibits activity
5b Stimulates activity
6 Liver
6a Glycogen conversion to glucose
6b Glucose conversion to glycogen
7 Adrenal gland
7a Stimulates release of

epinephrine and norepinephrine
7b Inhibits release of epinephrine and norepinephrine
8 Intestine
8a Inhibits peristalsis
8b Stimulates peristalsis
9 Bladder
9a Relaxes bladder
9b Contracts bladder

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Coordination: brain 1

05.036

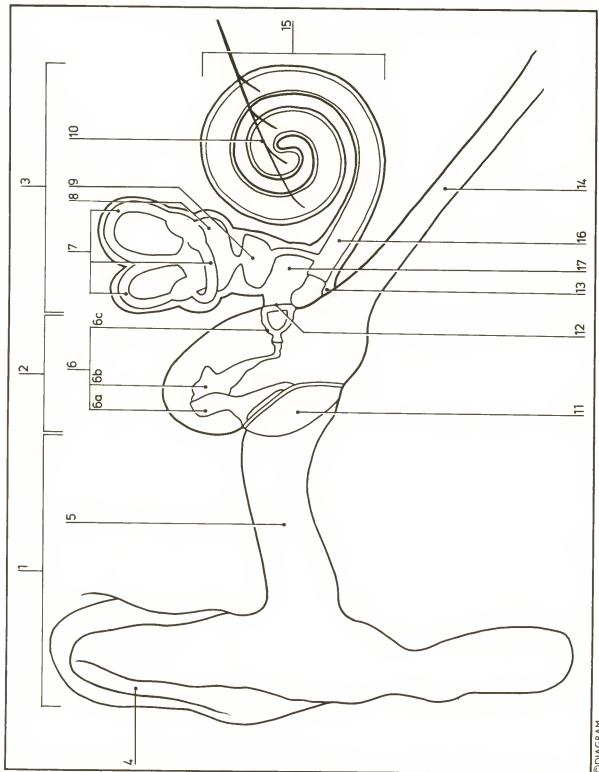


A Brain from left side
B Brain from left side
showing location of
areas

- | | |
|-----------------------|----------------------|
| 1 Frontal lobe | 5 Medulla oblongata |
| 2 Parietal lobe | 6 Spinal cord |
| 3 Cerebral hemisphere | 7 Cerebellum |
| 4 Temporal lobe | 8 Occipital lobe |
| | 9 Premotor area |
| | 10 Motor area |
| | 11 Sensory area |
| | 12 Motor speech area |
| | 13 Auditory area |
| | 14 Visual area |

Coordination: ear 1

05.041



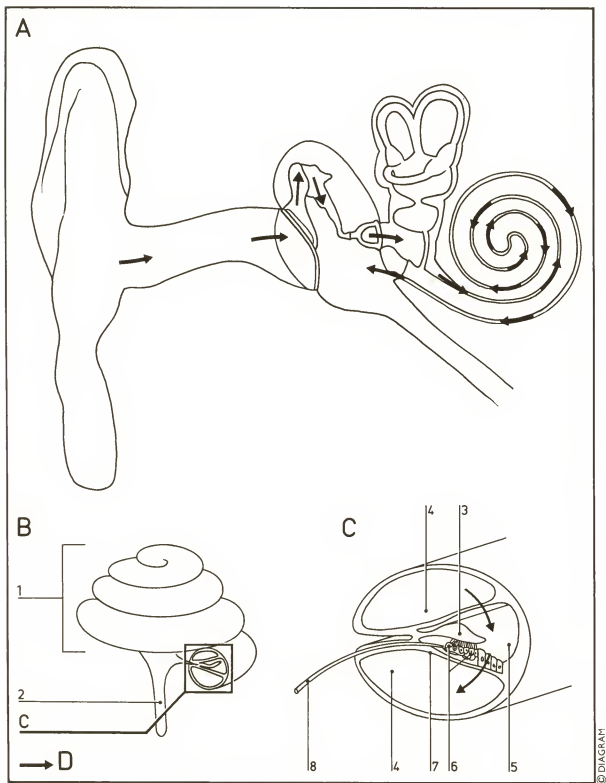
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Section of the head to show internal structure of the ear

- 1 Outer ear
- 2 Middle ear
- 3 Inner ear
- 4 Pinna
- 5 Ear canal
- 6 Ossicles
- 6a Hammer (malleus)
- 6b Anvil (incus)
- 6c Stirrup (stapes)
- 7 Semicircular canals
- 8 Utricle
- 9 Saccule
- 10 Auditory nerve
- 11 Eardrum (tympanum)
- 12 Oval window
- 13 Round window
- 14 Eustachian tube
- 15 Cochlea
- 16 Endolymph
- 17 Perilymph

Coordination: ear 2

05.042



Hearing

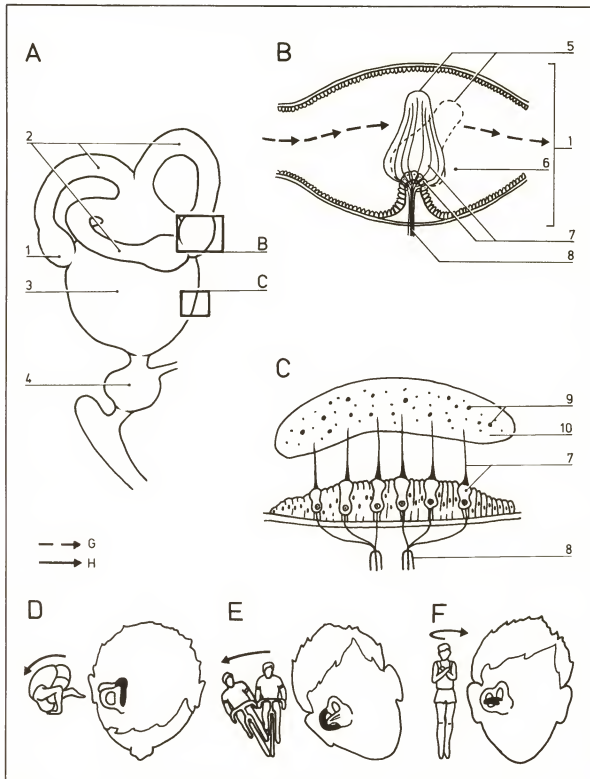
- A Passage of sound waves through the ear
B Side view of cochlea
C Cross section of cochlea
D Direction of sound waves

- 4 Perilymph
5 Endolymph
6 Sensory hair cell
7 Basilar membrane
8 Branch of auditory nerve

- 1 Cochlea
2 Auditory nerve
3 Tectorial membrane

Coordination: ear 3

05.043



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Balance

- A Structure of semicircular canals, utricle and saccule
B Section through ampulla
C Section through utricle
D-F Schematic view of

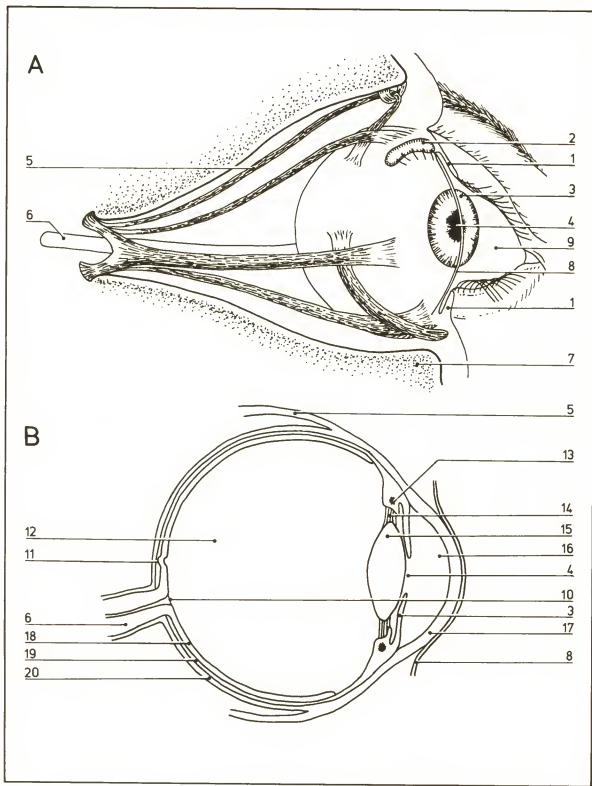
- semicircular canals showing stimulation of individual canals by different movements
G Movement of endolymph
H Movement of head

- 1 Ampulla
2 Semicircular canals
3 Utricle
4 Saccule
5 Cupula (displaced by endolymph)
6 Endolymph
7 Sensory hair cell
8 Sensory fiber

- 9 Otoliths
10 Jelly-like substance

Coordination: eye 1

05.044



A Partial section to show orbit and extrinsic muscles
B Vertical section

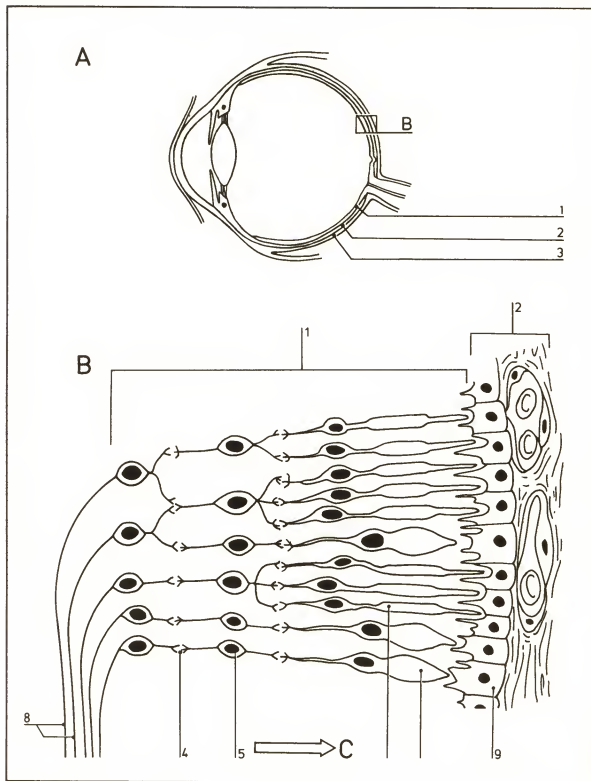
- 1 Eyelid
- 2 Tear gland
- 3 Iris
- 4 Pupil

- 5 Extrinsic muscle
- 6 Optic nerve
- 7 Bone of orbit
- 8 Conjunctiva
- 9 Eyeball
- 10 Blind spot
- 11 Fovea
- 12 Vitreous humor
- 13 Ciliary body

- 14 Suspensory ligaments
- 15 Lens
- 16 Aqueous humor
- 17 Cornea
- 18 Retina
- 19 Choroid
- 20 Sclera

Coordination: eye 2

05.045



A Vertical section
B Retinal structure
C Direction of light

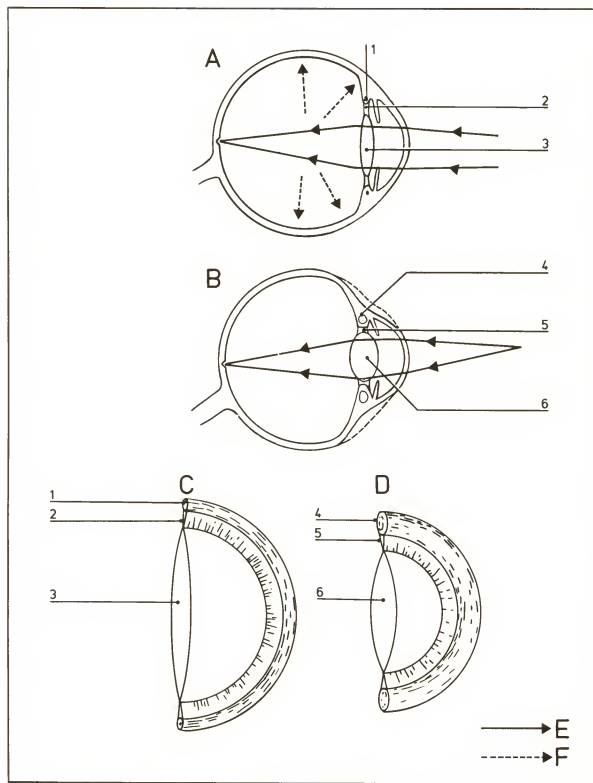
6 Rod
7 Cone
8 Sensory fibers
9 Pigment layer

1 Retina
2 Choroid
3 Sclera
4 Synapse
5 Association neuron

© DIAGRAM

Coordination: eye 3

05.046



Focusing

A & B Vertical section of eye to show focusing of light on fovea

C, D Section of lens and ciliary muscle to show focusing mechanism

A & C Distant objects

B & D Near objects

E Light ray

F Pressure of vitreous humor

1 Ciliary muscles relaxed

2 Suspensory ligaments pulled taut

3 Lens pulled thin

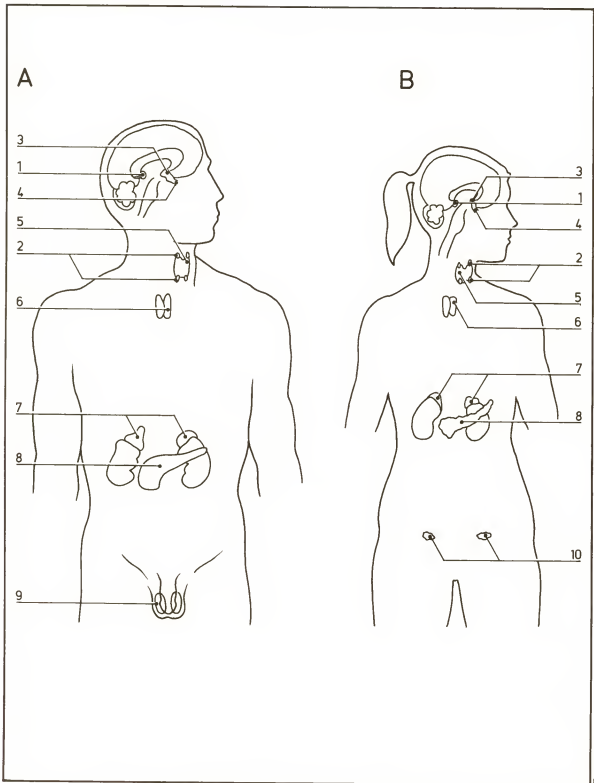
4 Ciliary muscles contracted

5 Suspensory ligaments slacken

6 Lens shrinks and thickens

Coordination: endocrine system

05.047



A Male
B Female

7 Adrenal glands
8 Pancreas
9 Testes
10 Ovaries

1 Pineal gland
2 Parathyroid glands
3 Hypothalamus
4 Pituitary gland
5 Thyroid gland
6 Thymus

Coordination: pituitary gland

05.048

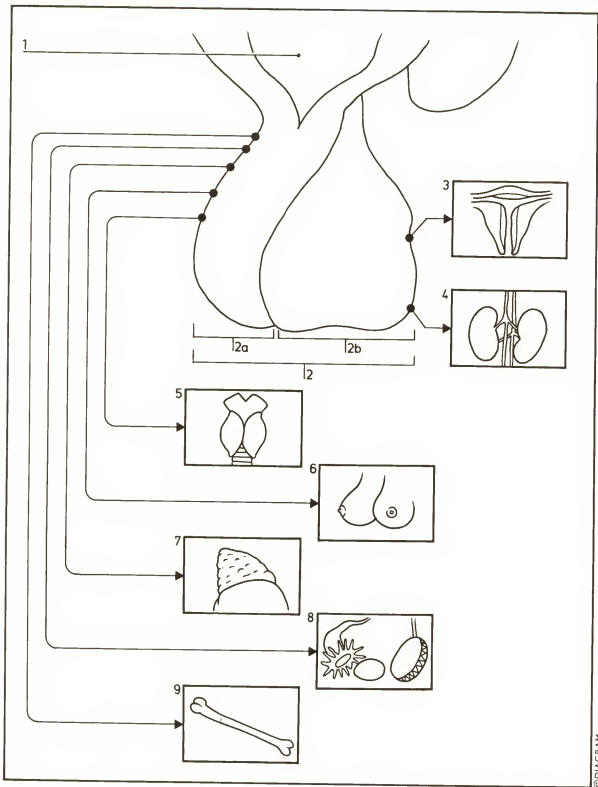


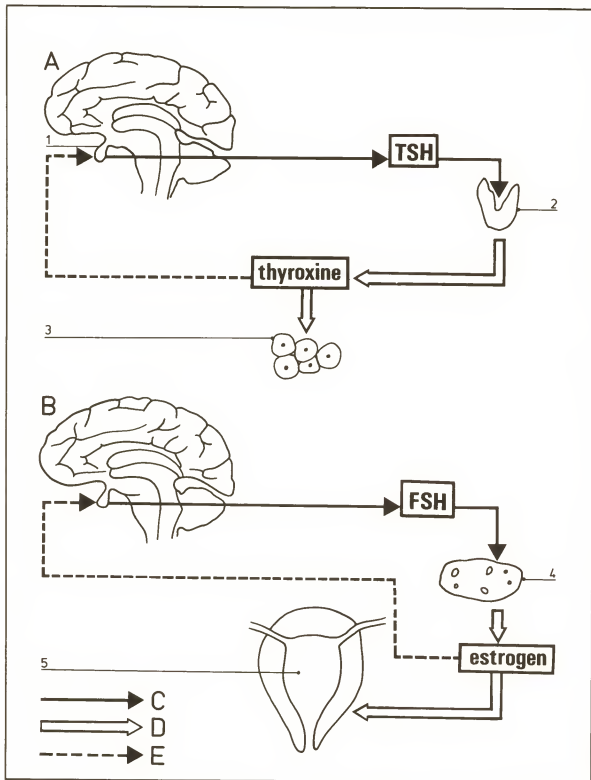
Diagram to show hormones produced by the pituitary gland

- 1 Hypothalamus
- 2 Pituitary
- 2a Anterior lobe
- 2b Posterior lobe
- 3 Oxytocin (contraction of smooth muscle of uterus)
- 4 Vasopressin (anti-diuretic hormone, reduces volume of urine produced by kidney)

- 5 Thyroid stimulating hormone (stimulates thyroid to produce thyroxine)
- 6 Prolactin (stimulates mammary glands to secrete milk)
- 7 Adrenocorticotropic hormone (stimulates adrenal cortex to secrete adrenocorticoid hormones)
- 8 Gonadotrophic hormone (stimulates ovaries or testes to secrete sex hormones)
- 9 Growth hormone (regulates growth in body)

Coordination: feedback mechanism

05.049



- A TSH produced by the pituitary stimulates release of thyroxine by the thyroid
B FSH produced by the pituitary stimulates release of estrogen by the ovary
C Hormones released by pituitary gland
D Hormones released by target glands
E Inhibitory feedback to pituitary by target gland hormone

- 1 Pituitary gland
2 Thyroid gland
3 Body cells
4 Ovary
5 Uterus

Coordination: menstrual cycle

05.050

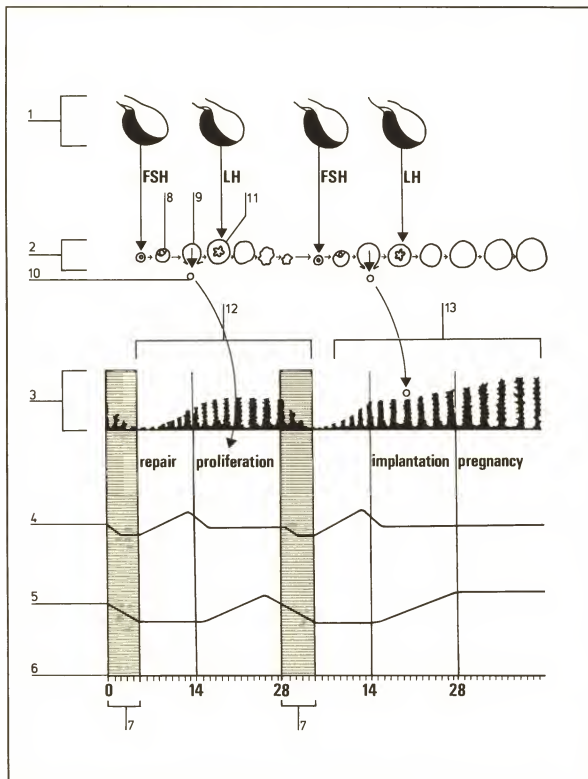


Diagram to show events of menstrual cycle without and with fertilization

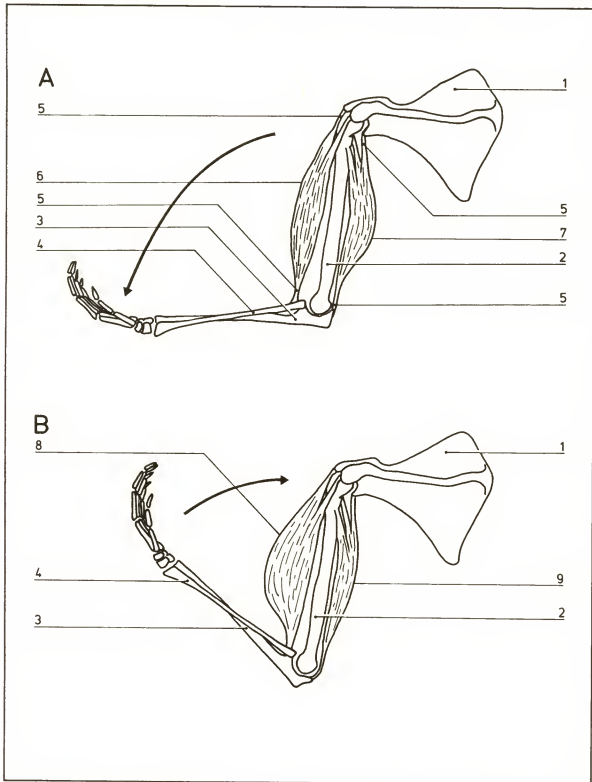
- 1 Pituitary gland
- 2 Development of Graafian follicle and corpus luteum in ovary
- 3 Wall of uterus
- 4 Estrogen level
- 5 Progesterone level
- 6 Time in days

- 7 Menstruation
- 8 Graafian follicle
- 9 Ovulation
- 10 Ovum
- 11 Corpus luteum
- 12 Ovulation without fertilization
- 13 Ovulation with fertilization

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Locomotion: limb movement

05.053



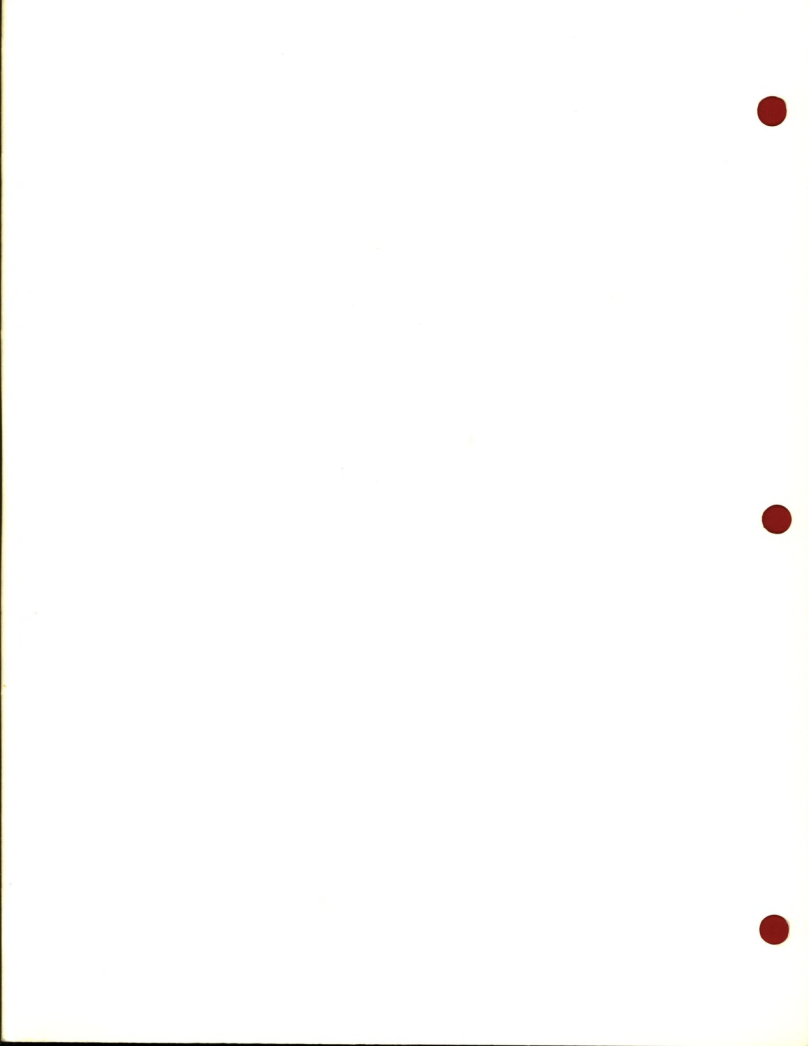
A, B Antagonistic muscles of the forearm

A Extended

B Flexed

- 1 Scapula
- 2 Humerus
- 3 Ulna
- 4 Radius
- 5 Tendon

- 6 Biceps relaxed
- 7 Triceps contracted
- 8 Biceps contracted
- 9 Triceps relaxed



Terrestrial biomes

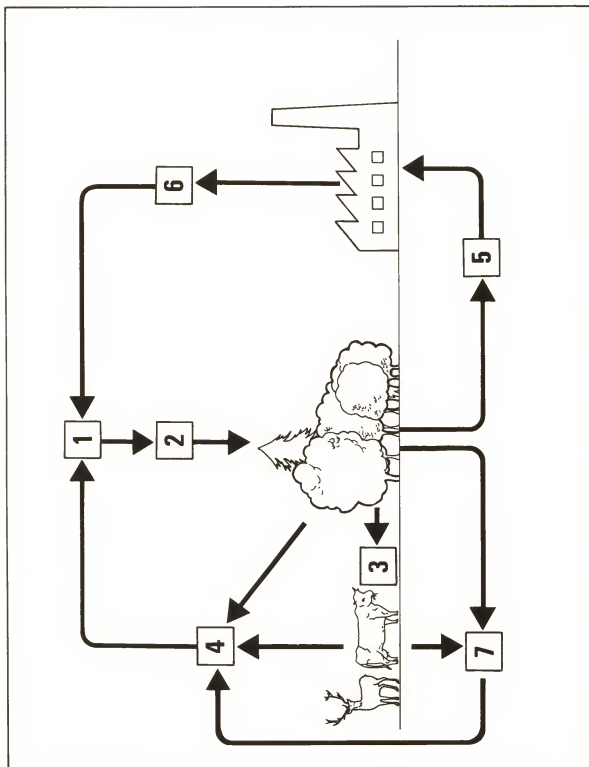
06.001



- A Rainforest
- B Desert
- C Grassland
- D Deciduous forest
- E Taiga
- F Tundra

Carbon cycle

06.002

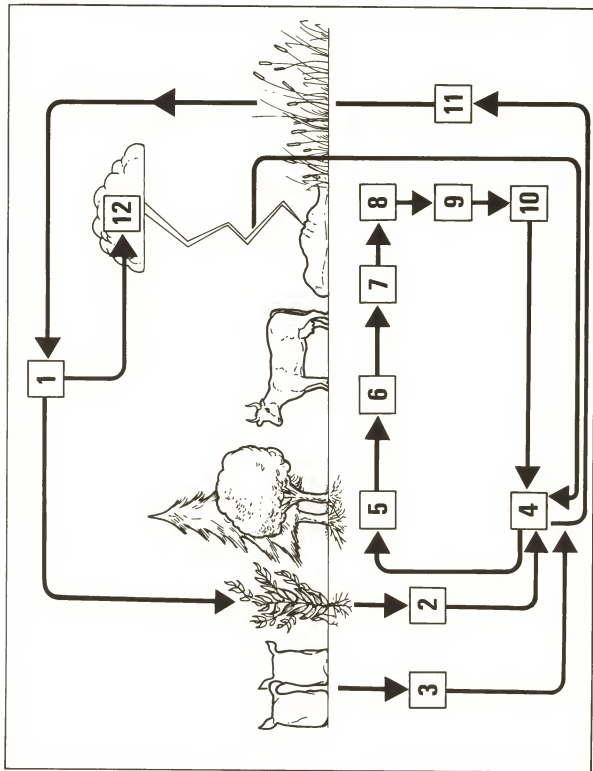


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- 1 Atmospheric pool of carbon dioxide
- 2 Plants take up carbon dioxide for photosynthesis
- 3 Animals eat plants
- 4 Carbon dioxide released by respiration
- 5 Fossil fuels released by combustion
- 6 Carbon dioxide released by death of organisms and decay by bacteria
- 7

Nitrogen cycle

06.003

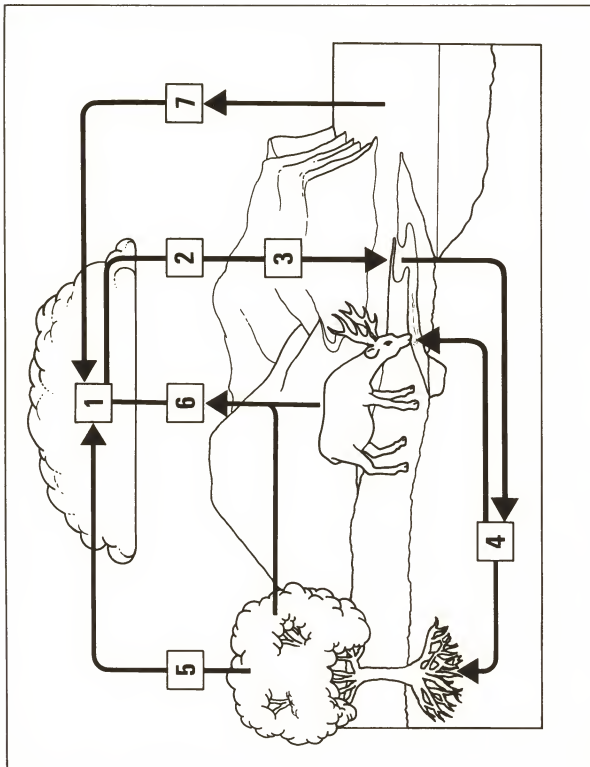


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- 1 Atmospheric pool of nitrogen
- 2 Nitrogen-fixing bacteria in root nodules of legumes
- 3 Fertilizers
- 4 Soil nitrate
- 5 Nitrate taken up by plant and animal proteins
- 6 Dead organisms
- 7 Decomposers
- 8 Nitrite bacteria
- 9 Nitrifying bacteria
- 10 Denitrifying bacteria
- 11 Lightning

Water cycle

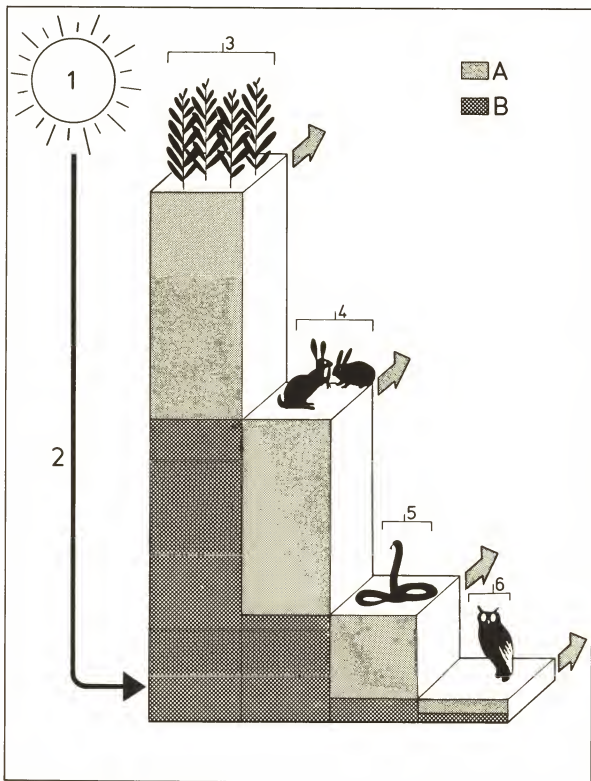
06.004



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Energy flow

06.005

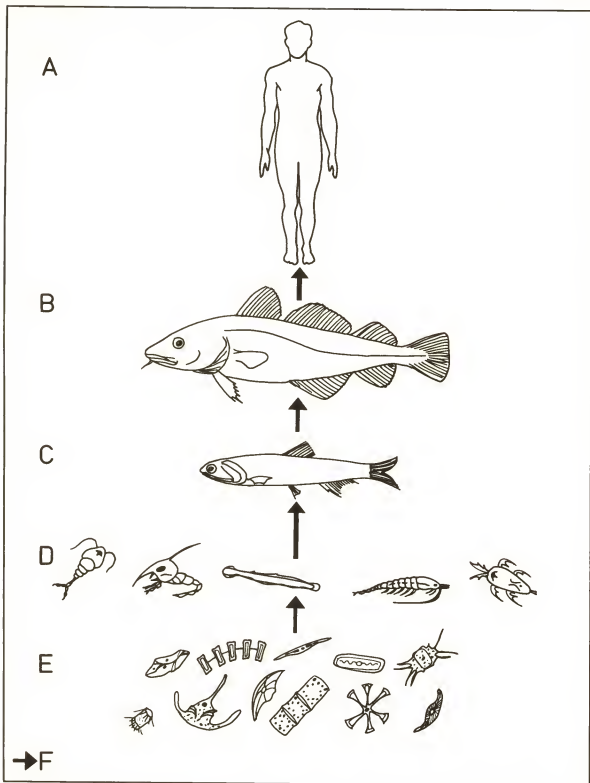


A Energy lost from the living system as heat
B Energy flowing through the living system

- 1 Sunlight energy
- 2 Sunlight energy captured by plants (producers)
- 3 Producer
- 4 Primary consumer
- 5 Secondary consumer
- 6 Tertiary consumer

Food chain

06.006

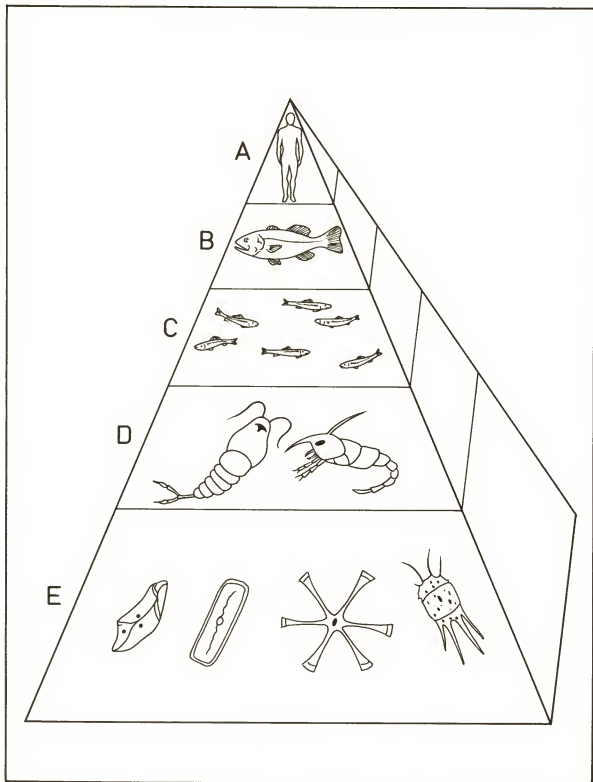


- A Human (quaternary consumer)
B Bass (tertiary consumer)
C Minnows (secondary consumer)
D Animal plankton (primary consumer)
E Algae (producer)
F Direction of energy flow

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Pyramid of biomass

06.007

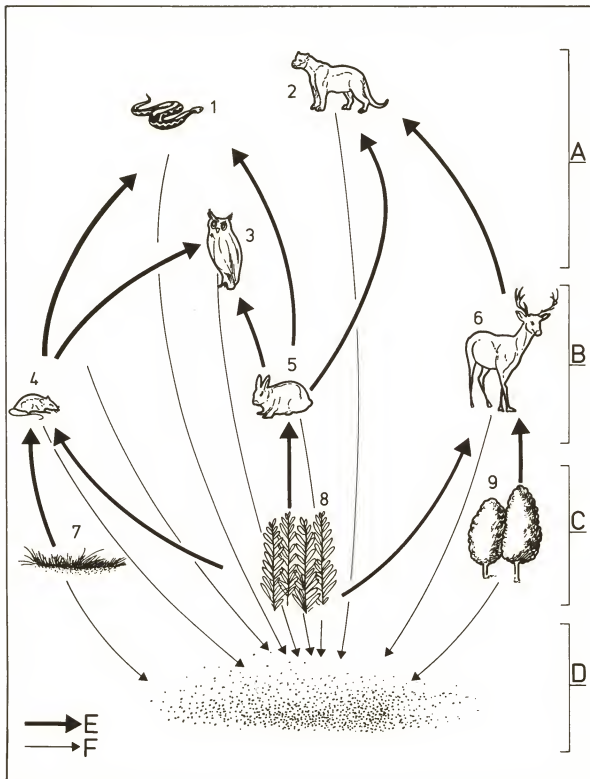


- A Human (1 kg)
B Bass (10 kg)
C Minnows (100 kg)
D Animal plankton (1,000 kg)
E Algae (10,000 kg)

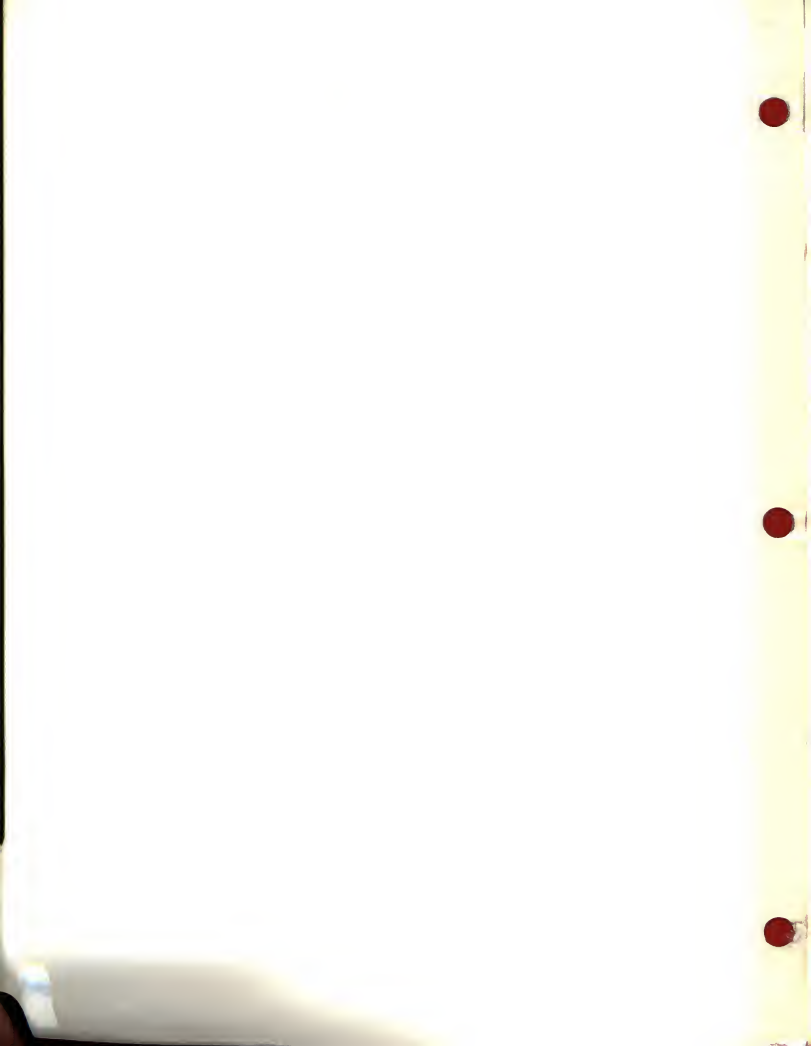
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Food web

06.008



- | | |
|-----------------------|-----------|
| A Secondary consumers | 3 Owl |
| B Primary consumers | 4 Mice |
| C Producers | 5 Rabbits |
| D Decomposers | 6 Deer |
| E Eaten by | 7 Grass |
| F Decomposed | 8 Crops |
| | 9 Trees |
| 1 Snake | |
| 2 Mountain lion | |





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